Popular Astronomy.

Vol. V. No. 6. OCTOBER, 1897. Whole No. 46.

ON THE PHOTOGRAPHY OF METEORS.

E. E. BARNARD.

FOR POPULAR ASTRONOMY.

The subject of meteor photography becomes of more and more interest as the return of the great Leonid display approaches, for it is to the camera that astronomers will look for the most important and interesting results on that occasion.

There has been no opportunity, since the practical advent of the rapid dry plate, to photograph a meteoric shower and the results of efforts in this line during the next three or four years, will be looked forward to with the keenest interest. For my part I see no reason why, with our present understanding of the subject, we should not secure a magnificent record which will be of the highest importance to meteoric astronomy.

In my photographic work of the last six or eight years, I have, on a number of occasions, secured trails of meteors on the star plates. Some of these have been from the passage of very large meteors. Several times these meteors have been seen in their flight with the eye, and on one occasion a bright stationary meteor was photographed. It is therefore not an uncommon thing to secure meteor trails where one is frequently photographing the sky—especially if he should use a quick working lens of the portrait combination with as wide and flat a field as possible.

The portrait lens has proved its value for all work of this class so emphatically that no one who can get such an instrument will attempt to use anything else for the purpose. Yet, in the case of a great shower like the one promised, I do not despair of a long focus lens doing very valuable work because of the bigger image and the advantages of detail which may occur in the event of the explosion of a large meteor. But the most interesting and important work will undoubtedly be done by the short focus portrait lens.

Where the scale does not become too important a factor, there are many advantages in using a comparatively small lens, such for instance as the one used by the writer in making a great number of star pictures at the Lick Observatory. This lens, as I have shown previously (*Astronomy and Astro-Physics* No. 130,

A. P. J. Dec. 1895, etc.) is far more rapid than the larger portrait lenses and gives a wider field though the scale is necessarily small. Its diameter is 1½ inch and 5.3 inches focus. This is the kind of lens used in the ordinary projecting lantern and can be purchased for a few dollars. From the fact that it belonged to a common magic lantern, I have called it the "lantern lens". Such a lens is within the reach of every amateur either by purchase or loan. I would, however, caution anyone from using the visual focus of such a lens. It is best to determine the focus by star trails. In using such a lens for meteors it is best to have it attached to an equatorial with clock motion, though this is not altogether necessary. Very valuable results can be obtained by simply pointing the instrument in the direction of some known star and fastening it to a board tilted in the proper position—the beginning and ending of the exposure being noted. The star trails will enable one to properly locate the position of any meteor trail which may appear on the plate if the time of the meteor's flight is noted. The plates should be frequently changed and marked to avoid confusion as to the time of the meteor's appearance. An eye should also be kept to the sky and every meteor that crosses the region of the plate should be noted for time and rough location.

Very important work can be done—especially by those not provided with equatorial telescopes—if two or more are provided with cameras and are stationed several miles apart with their instruments simply directed towards the zenith for the determination of the parallax of the meteors, as described by Professors Schaeberle and Colton of the Lick Observatory in POPULAR ASTRONOMY for September.

It is a misfortune that the moon will interfere to a certain extent during the several years in which we may have meteoric showers at the close of the present century. It will be specially bad in 1899; there will be no interference, however, in 1898 and not very much in 1900. In the present year, 1897, whatever shower may occur will happen in the presence of a gibbous moon, which will interfere more or less seriously with visual observations. So far, however, as the photographic results are concerned it will not be so serious an objection as may be supposed. With comparatively short exposures, even a full moon lit sky would not interfere seriously so far as fogging the plates is concerned.

I have recently, and previously, made some experiments in this direction and the results have been somewhat surprising to me.

I find that from half an hour to an hour's exposure with the ordinary portrait lense on a sky illuminated by the full moon does not seriously fog the plate. Great care, however, should be taken in the development to hold back the sky illumination as much as possible. Even with the quick acting lantern lens an exposure of an hour is possible on a full moonlit sky with a quick plate. The question may come up as to what effect such conditions would have on photographing a faint object. Such as a small meteor train. While I believe that small meteor trains might be missed under these circumstances that would be caught on a dark sky, I do not know that such is the case. I have made some experiments that possibly bear on this subject and whether they do or not they are interesting just now.

The diffused nature of the celebrated Merope Nebula of the Pleiades is well known. Such an object, visually, cannot stand much illumination of the sky.

On the night of September 30, 1895, (my last night on Mt. Hamilton) I gave an exposure of 20 minutes—from $14^h\ 34^m$ to $14^h\ 54^m$—on the Pleiades with the Willard lens. The moon was then some two days of full, and the night was very brilliant with its illumination. This illumination of the sky did not materially affect the plate. To my surprise the Merope Nebula came out strong and distinct in its full extent. Some of the other nebulosities of the Pleiades were also shown faintly, especially the prong like projection from Electra. These objects would have been utterly invisible, visually, under such conditions with any telescope. Stars of the 12th to the 13th magnitude are clearly shown. The smallest star, by reference to the Paris maps, being about 13th mag. An exposure of 9 minutes was also given at this time. Very faint traces of the Merope Nebula can be seen on this plate also.

In some of my comet photographs the exposure has been carried on in more or less strong moonlight without any apparent bad effects. I think therefore, so far as the photographic results are concerned, we need not worry over the presence of the moon, certainly not so far as the chances of fogging the plate are concerned. For various reasons, however, the plate should not be exposed too long.

With this paper are four meteor photographs. The first one of these shows a magnificient meteor trail on the same plate with Brooks comet.

This photograph was made on the morning of Nov. 14, 1893, when a great many Leonids were present. Singularly enough,

however, this fine meteor did not belong to the Leonids. As will be seen, its flight was from the direction of the north pole and at right angles to the direction of the the Leonid radiant. The large star shown to the side of the picture is α Canum, and the one nearer the comet is 14 Canum. The scale of this picture is about 2° to the inch, a slight reduction from the original. The ephemeris position of the comet was $\alpha = 13^h\ 8^m\ \delta = +34°.5$.

The photograph of the stationary meteor was obtained 1894, Aug. 9. The approximate position of the meteor is

$$\alpha = 2^h\ 57^m;\ \ \delta = +57°.7$$

Mr. Perrine, who was observing the meteors visually, saw this object and recorded the exact time of its appearance. Pacific Standard Time $14^h\ 17^m\ 4^s$.

The scale of this photograph is 1 in. = 1°.9.

These two pictures were made with the Willard lens of the Lick Observatory. The given times are 8 hours slow of Greenwich.

The other two photographs were made here on the morning of August 11th, 1897. They are both of the same meteor. The larger one was made with a portrait lens 3.4 in. in diameter and 19.4 in. focus by the late lamented Alvan G. Clark and kindly loaned by his family. It is made from the same glass and with the same curves as the Bruce 24-inch portrait lens of Harvard College Observatory and is indeed an exact miniature of that lens. The scale of this picture is 1 inch = 3°. The smaller picture is with a small lantern lens belonging to Professor Hale, 1.6 in. diameter and 6.4 inches focus. The scale of this picture is 1 inch = 9°. The exposure was in both cases from $15^h\ 19^m$ to $15^h\ 49^m$. (This time being 6 hours slow of Greenwich.) It will be seen that the meteor did not pass across the center of the plate in either case, but near the edge of the field.

The trail extends from

$$\alpha = 2^h\ 59^m,\ \delta = +32°$$
$$\text{to}\ \alpha = 2\ \ 59\ \ ,\ \delta = +23$$

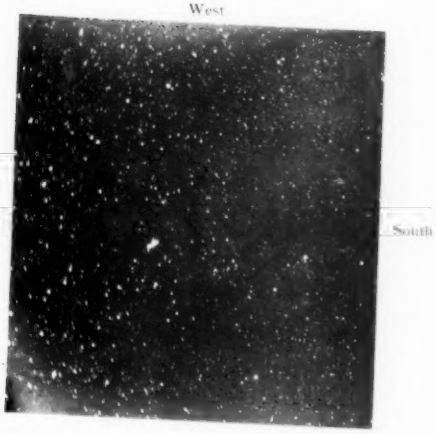
(See Popular Astronomy for Sept., p. 272–3 and interchange the declinations given there.

The star just east of the trail near the head of the meteor is 52 Arietis.

The group of stars in the small picture is of course the Pleiades.

Yerkes' Observatory, Williams Bay, Wis.,
1897, Sept. 8.

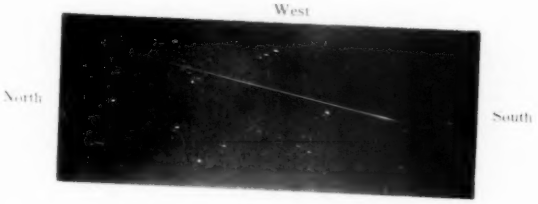
PLATE XXI.



PHOTOGRAPH OF NEARLY STATIONARY METEOR.

1894, Aug. 9. Exposure $12^h.\ 30^m. - 15^h.\ 45^m.$

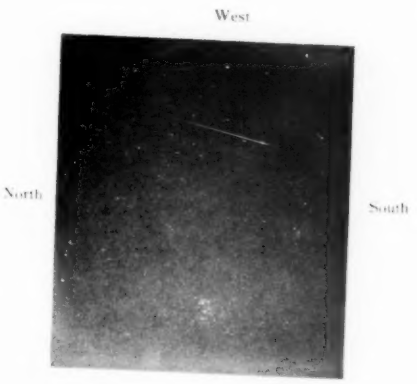
E. E. BARNARD.



1897, Aug. 10. $15^h.\ 19^m. - 15^h.\ 49^m.$

Clark Lens.

E. E. BARNARD.



1897, Aug. 10. $15^h.\ 19^m. - 15^h.\ 49^m.$

Lantern Lens.

E. E. BARNARD.

Reproduced by Chicago Photo-Gravure Co.

A MICROMETRICAL DETERMINATION OF THE DIMENSIONS OF THE PLANETS AND SATELLITES OF THE SOLAR SYSTEM MADE WITH THE 36-INCH REFRACTOR OF THE LICK OBSERVATORY.

E. E. BARNARD.

FOR POPULAR ASTRONOMY.

The writer has been repeatedly asked for the dimensions of the planets determined by him while at the Lick Observatory. These measures have been published in different astronomical journals, *A. and A. P.*, *A. J.*, *M. N.*, *A. P. J.*, etc. In one or two cases preliminary measures were printed which may be accidentally used instead of the final and adopted values. I have thought the general interest attached to the measures might warrant a collection and general revision of them for publication in POPULAR ASTRONOMY, where they will be accessable to those interested in the matter. These measures were all made with the filar micrometer of the 36-inch refractor of the Lick Observatory—except those of Mercury, which were obtained with the 12-inch at the transits of 1891 and 1894. Throughout, the measures were made by the method of double distances. Usually five settings were made in each position of the wire, the entire work requiring over four thousand two hundred individual settings of the wires. For, the asteroids, Uranus and Neptune and the satellite measures, 1000 diameters was uniformly used, while the measures of Mars, Jupiter and Saturn were made with 520 diameters.

MERCURY.

This planet was observed at the transits of 1891 and 1894 under favorable conditions with the 12-inch refractor. The aperture was reduced to 4 inches in 1891 and to 5 and 6 inches in 1894.

In the measures of 1891 the apparent diameter of Mercury was 10″.9 while in 1894, in the opposite part of the orbit, it was 9″.2.

1891, MAY 9.

"Polar" diameter observed.	"Equat." diameter observed.
10″.76 (5 obs.)	10″.81 (5 obs.)
10.71 (3 ")	10.57 (3 ")
10.92 (3 ")	11.25 (3 ")
10.797 (11 obs.)	10.877 (11 obs.)

Different magnifying powers, from 150 up to 500 were employed.

The planet could not be seen without telescopic aid, for a careful search with smoked glass and eye alone failed to show it.

1894 Nov. 9-10.

"Polar" diameter observed.	"Equat." diameter observed.
8.83 (5 obs).	9.15 (4 obs).
9.41 (5 ")	8.99 (5 ")
9.26 (4 ")	9.35 (5 ")
9.07 (5 ")	9.59 (5 ")
9.59 (5 ")	9.18 (5 ")
	9.17 (5 ")
9.144 (24 obs.)	9.237 (29 obs.)

Each observation is the mean of five double distance measures.

These values of the diameter of Mercury reduced to the Sun's mean distance, give

1891	Polar diameter	6.020
	Equat. diameter	6.065
1894	Polar diameter	6.178
	Equat. diameter	6.241
		6.126

At each transit the measures were made in two directions—"Equatorial," or right ascension and "Polar" or declination.

These persistently indicate a slight polar flattening of about $\frac{1}{116}$. This is, however, very uncertain, and if real, must be smaller than the true value because of the unknown position of the axis of rotation.

No indications of an atmosphere were detected, though looked for. The planet could not be seen except where projected on the Sun. It was apparently lighter however, than the darkness outside the Sun's disc as shown by contrast with a wire laid across the image of the planet and the sky. This, possibly, may have been an optical effect of some kind.

On this last occasion, also, a careful search failed to show Mercury without telescopic aid. It was easily visible however with a very small telescope (object glass 1.38 in. diameter and 5-inches focus) which magnified 2¼ times. With this same glass in 1891, Mr. Burckhalter of the Chabot Observatory at Oakland, California, had seen the planet in transit. It is therefore evident that though Mercury cannot be seen at any of its transits with the unaided eye, it would require a magnification of only a couple of diameters to show it distinctly at such times *

On both occasions, a careful search was made for any possible satellite.

* In this connection the distinction between the visibility of a black spot and a black line is very interesting. Mercury could not be seen with the unaided eye—though it subtended an angle of nearly eleven seconds. I have recently made some experiments in this line. A small wire whose diameter was 0.009 of an inch, suspended against the bright sky, was distinctly seen with the unaided eye at a distance of 356 feet. At that distance it subtended an angle of only 0".44!

Venus.

The measures were made with the great telescope when the planet was approaching inferior conjunction, and are of the diameter perpendicular to the orbit of Venus. The customary west wind that springs up nearly every evening during the summer months at Mt. Hamilton interfered very much with the observations, often making it impossible to secure measures.

Two magnifying powers were used, 350 and 520. The smaller of these was generally preferred, as the measures were less affected by the oscillation of the image due to wind. One or two measures are rather discordant, but these can be attributed to the conditions of observation—shaking of the telescope by the wind or poor definition.

Diameter of Venus.

	St. Pac. Time.			Sun Set.				
1895	d	h	m	h	m	Mag. Power	Observed.	at Δ 1
							″	″
May	6	7	6	6	59	350	14.43	17.30
	6	7	16	.	..	520	14.61	17.51
	12	7	30	7	4	520	14.99	7.35
	13	6	56	7	5	520	15.04	17.30
	13	7	3	.	..	350	14.83	17.06
June	2	6	54	7	20	520	17.16	17.23
	2	7	2	.	..	350	17.19	17.25
	3	7	20	7	20	350	17.52	17.45
	9	6	48	7	24	350	18.44	17.51
	9	6	58	.	..	520	18.27	17.35
	10	7	58	7	25	350	19.26	18.13
	16	6	17	7	27	350	19.36	17.32
	16	6	20	.	..	520	19.35	17.31
	17	7	5	7	27	350	19.99	17.73
	17	7	10	.	..	520	20.10	17.83
	24	7	25	7	29	350	20.59	17.10
	30	6	25	7	29	350	22.23	17.39
	30	6	30	.	..	520	22.33	17.47
July	1	7	23	7	29	350	22.33	17.28
	1	7	29	.	..	520	22.65	17.53
	7	7	55	7	28	350	24.38	17.67
	8	7	27	7	28	350	24.03	17.23
	14	7	10	7	26	350	25.57	17.09
	14	7	18	.	..	520	25.63	17.13
								17.397

Mars.

During the opposition of Mars in 1892 and 1894 a series of observations of the satellites and the surface markings of the planet were made with the 12-inch and 36-inch equatorials. A long series of measures of the diameters of the south polar cap was made, also, at each opposition; these have already been published in Popular Astronomy for June, 1895. The drawings of the planet have not yet been published.

In the following measures of the diameter of Mars, the "polar"

diameter is that one through the south polar cap, and the "equatorial" diameter is the one at right angles to it. I think there is no question as to the measurable ellipticity of the planet, and that the polar compression is greater than that required by the present rotation period of Mars.

DIAMETERS OF MARS.

1894	d	h	m	Polar Diameter Observed	Polar Diameter at $\Delta 1$	D
				"	"	"
July	30	18	0	13.52	9.46	9.45
Aug.	13	17	52	15.06	9.43	9.42
Sept.	30	12	40	21.50	9.50	9.49
Oct.	7	14	15	22.04	9.53	9.52
	15	9	50	22.58	9.75	9.74
	21	9	45	22.05	9.67	9.66
	28	10	10	21.31	9.65	9.64
	29	8	30	21.26	9.68	9.67
Nov.	4	9	15	20.24	9.61	9.60
	5	9	15	20.22	9.64	9.63
	11	8	40	19.05	9.58	9.57
						9.581

D is the final value at $\Delta 1$ corrected for inclination of the axis.

1894	d	h	m	Equatorial Diameter Observed	Equatorial Diameter at $\Delta 1$
				"	"
July	30	17	55	11.55	9.45
Oct.	7	14	10	22.16	9.69
	15	9	45	22.68	9.81
	21	9	40	22.18	9.73
	28	10	15	21.32	9.67
	29	8	35	21.27	9.73
Nov.	4	9	10	20.12	9.67
	5	9	10	20.06	9.69
	11	8	45	18.67	9.62
					9.673

These measures have been corrected for phase.

The diameters give for the polar compression of Mars

$$\frac{E-P}{E}=\frac{1}{105}.$$

which is a little smaller than the mean of the various results obtained by other observers, though it is larger than theory requires.

THE ASTEROIDS.

CERES (1.)

1894	d	Obsd.	At Δ 2.7673
		"	"
March	12	0.75	0.44
	25	0.72	0.43
April	1	0.73	0.44
	9	0.58	0.36
	16	0.60	0.39
	23	0.59	0.40
	30	0.58	0.40

1894	d	Obsd.	At Δ 2.7673
		"	"
May	7	0.47	0.34
1895			
May	12	0.53	0.40
	13	0.56	0.42
June	2	0.60	0.41
	3	0.56	0.39
	17	0.67	0.45
	23	0.47	0.32
	24	0.64	0.43
	30	0.48	0.32
July	1	0.63	0.43
	7	0.62	0.43
	8	0.48	0.33
	14	0.55	0.38
	15	0.57	0.40
Aug.	4	0.44	0.33
	5	0.43	0.32
			0.389

At distance 1 this = 1."076.

PALLAS (2.)

1894		Obsd.	At Δ 2.7673
		"	"
Feb.	25	0.75	0.34
	26	0.59	0.26
March	11	0.44	0.21
	12	0.46	0.21
	25	0.40	0.20
			0.244

At distance 1 this = 0."675.

JUNO (3).

1895		Obsd.	At Δ 2.7673
		"	"
July	21	0.16	0.11
	22	0.14	0.10
Aug.	4	0.12	0.09
	5	0.11	0.08
			0.095

This value for Juno at distance 1 becomes 0."263.

VESTA (4.)

1894		Obsd.	At Δ 2.7673
		"	"
March	11	0.38	0.23
	12	0.46	0.22
	25	0.33	0.16
Apr.	1	0.39	0.20
	9	0.29	0.15
1895			
July	7	0.35	0.19
	8	0.44	0.24
	14	0.41	0.21
	15	0.42	0.22
	21	0.38	0.19
	22	0.38	0.19

1894		Obsd.	At Δ 2.7673
		"	"
Aug.	4	0.40	0.19
	5	0.42	0.20
	11	0.43	0.20
	12	0.35	0.17
	18	0.43	0.20
	19	0.40	0.19
	25	0.40	0.19
			0.195

or at Δ 1 = 0".540

The value for Juno is a maximum because the planet was at the limit of measurement with the 36-in. The diameter may be somewhat smaller than this. On account of the high excentricity (0.257) of the orbit of Juno, the planet is not favorably placed, for observation, at each opposition. The opposition of 1894 was unsuited for dinmeter measures on account of the great distance. That of December 1896, however was extremely favorable for this work, and it was with the utmost regret that I saw the opportunity pass without being able to secure any measures. I have not heard that any one measured the planet on that occasion. There will be no favorable opposition until September 1900, when the planet will again make a close approach, but it will not even then be so favorably placed as in 1896, since it will run 6° or 8° south of the equator at the nearest approach. This, however, may be more or less compensated for as the opposition will fall in a very favorable part of the year for observation here.

Dr. G. Müller (No. 30 of the Publications of the Astro-Physical Observatory of Potsdam) has determined the albedos of the different planets. His values are

	Albedo.
Mercury	0.64
Venus	3.44
Mars	1.00
Jupiter	2.79
Saturn	3.28
Uranus	2.73
Neptune	2.36

From the preceding measures of the diameters of the asteroids and Dr. Müller's photometric determinations of their light, I have deduced the following table of albedos or reflective powers for these bodies, assuming, as Dr. Müller has, the albedo of Mars = 1.

	Albedo.
Ceres	0.67
Pallas	0.88
Juno	1.67
Vesta	2.77

If we compare these with the values obtained by Dr. Müller

for the major planets we find that Ceres reflects light with about the same intensity as Mercury, Pallas somewhat less than Mars, Juno between that of Mars and Jupiter, while Vesta is about equal in reflective power to Jupiter. The mean albedo of the four is 1.45.

Vesta, previous to these measures, has always been considered, from its generally greater brightness, to be the largest of the asteroids. This is due to the high albedo of its surface, for it reflects light with four times the intensity of Ceres. It will be seen also that Ceres is by far the largest of the asteroids.

Up to the time of these measures, none of the asteroids had ever been satisfactorily measured. So small are these little planets that all the telescopes which had been applied to them were inadequate to deal with their minute images. Various efforts had been made to photometrically determine their sizes. But these always rested on an unwarranted assumption as to their albedos or reflective powers, and from that very reason the results could scarcely be even approximately true. Upon examining the larger asteroids with the 36-in., I found that their discs could be seen and, with sufficient care, accurately measured, and this led me to take up their observation.

During these measures, no markings were seen upon any of these bodies, nor were any evidences visible of the dense atmospheres that have been ascribed to certain of them.

Jupiter.

The measures of the planet Jupiter were taken up in connection with the observations of the new satellite, and were distributed over nearly the entire period of observation of that object.

Diameters of Jupiter.

Greenwich M. T.			Equatorial Diameter				Polar Diameter.	
1892	d	h	Observed.	Phase.	Obs'd Cor.	at Δ 5.20	Observed.	at Δ 5.20
			"	"	"	"	"	"
July	8	23.5	40.44	+ 0.43	40.87	38.81	38.19	36.26
	15	23.7	41.37	+ 0.44	41.81	38.84	....	....
	22	23.6	42.27	+ 0.44	42.71	38.80	39.87	36.22
	29	23.0	43.00	+ 0.44	43.44	38.59	40.85	36.29
Aug.	5	23.5	44.08	+ 0.42	44.50	38.65	41.58	36.11
	12	23.5	44.78	+ 0.39	45.17	38.38	42.83	36.39
Sept.	10	22.5	48.93	+ 0.16	49.09	38.59	....	....
	11	21.5	49.11	+ 0.15	49.26	38.64	....	....
	12	22.0	48.97	+ 0.14	49.11	38.45	46.01	36.02
	13	20.5	....	...	....	....	46.10	36.03
	14	20.0	49.18	+ 0.13	49.31	38.46	46.03	35.90
	16	20.0	49.98	+ 0.11	50.09	38.92	46.57	36.19
	23	19.5	50.24	+ 0.06	50.30	38.68	47.36	36.42
	26	1.0	50.26	+ 0.05	50.31	38.58	....	....
	27	20.5	....	...	....	....	47.25	36.17

Greenwich M. T. 1892 d	h	Equatorial Diameter. Observed.	Phase.	Obs'd Cor.	at Δ 5.20	Polar Diameter. Observed.	at Δ 5.20
		"	"	"	"	"	"
Oct. 1	21.0	50.26	+ 0.02	50.28	38.35	....	....
2	21.0	50.20	+ 0.02	50.22	38.28	....	....
7	20.0	50.51	0.00	50.51	38.42	46.93	35.69
9	19.5	50.80	0.00	50.80	38.62	....	....
16	21.2	50.25	0.00	50.25	38.25	48.13	36.64
21	19.0	49.95	+ 0.02	49.97	38.16	46.90	35.81
23	18.0	49.81	+ 0.03	49.84	38.12	46.85	35.84
28	17.7	49.89	+ 0.05	49.94	38.65	46.66	35.90
Nov. 4	17.1	49.18	+ 0.10	49.28	38.33	45.87	35.68
6	17.0	49.15	+ 0.11	49.26	38.45	....	....
11	16.0	48.53	+ 0.15	48.68	38.40	45.93	36.23
13	16.0	48.29	+ 0.17	48.46	38.40	....	....
20	16.1	47.40	+ 0.23	47.63	38.41	44.72	36.06
1893							
Sept. 3	22.4	42.03	+ 0.41	42.44	38.39	....	....
15	23.7	43.96	+ 0.38	44.34	38.62	....	....
24	22.7	45.45	+ 0.33	45.78	38.80	....	....
Oct. 2	23.8	46.28	+ 0.28	46.56	38.58	....	....
Nov. 6	18.8	49.70	+ 0.03	49.73	38.65	46.49	36.17
19	17.5	50.00	+ 0.00	50.00	38.73	46.87	36.30
Dec. 10	17.0	....	...	....	....	45.56	36.03
1894							
Feb. 25	14.8	38.06	+ 0.35	38.41	38.24	36.18	36.02
26	14.7	38.22	+ 0.35	38.57	38.52	36.40	36.35
					38.522		36.112

These measures give for the polar compression

$$\frac{E-P}{E}=\frac{1}{15.98}$$

The Four Bright Satellites of Jupiter.

Satellite I.

1894		Observed. "	Δ 5.20 "
Oct.	21	1.08	0.97
	28	1.02	1.12
	29	1.13	0.99
Nov.	4	1.19	1.07
	5	1.33	1.14
	12	1.27	1.07
	18	1.24	1.03
	19	1.19	0.99
			1.048

Satellite II.

1894		Observed. "	Δ 5.20 "
Oct.	21	0.82	0.73
	28	0.93	0.81
	29	0.96	0.84
Nov.	4	1.05	0.90
	5	1.21	1.04
	12	1.10	0.93
	18	1.03	0.85
	19	1.08	0.89
			0.874

SATELLITE III.

1894		Observed.	Δ 5 20
		"	"
Oct.	21	1.85	1.66
	28	1.60	1.40
	29	1.66	1.45
Nov.	4	1.75	1.48
	5	2.03	1.74
	11	1.86	1.57
	12	1.77	1.49
	18	1.79	1.49
	19	1.86	1.54
Dec.	23	1.79	1.43
			1.521

SATELLITE IV.

1894		Observed.	Δ 5.20
		"	"
Oct.	21	1.58	1.41
	28	1.58	1.38
	29	1.58	1.38
Nov.	4	1.62	1.39
	5	1.85	1.58
	11	1.73	1.46
	12	1.69	1.42
	18	1.66	1.38
	19	1.77	1.47
			1.430

SATURN.

Careful measures of the entire Saturnian system were made in 1894 and 1895, including measures of the diameter of Titan—the largest satellite.

DIAMETERS OF SATURN.

EQUATORIAL DIAMETER.

1894		Observed.	Δ
		"	"
March	25	19.21	17.58
April	9	19.50	17.77
	16	19.52	17.80
	23	19.33	17.67
	29	19.44	17.83
	30	19.29	17.70
May	7	19.30	17.81
	21	19.10	17.89
	28	18.73	17.71
June	11	18.40	17.77
	18	18.18	17.76
	25	17.85	17.64
1895			
March	4	18.43	17.58
	10	18.37	17.96
April	7	19.17	17.75
	14	19.41	17.92
May	6	19.12	17.68
	12	19.23	17.84
June	17	18.73	18.08
July	1	18.25	17.99
	8	18.08	18.03
			17.798

The equatorial diameter is corrected for phase.

POLAR DIAMETER.

1894		Observed.	Δ	D
		"	"	"
March	25	17.80	16 29	16.20
April	9	17.97	16.38	16.29
	16	18.02	16.43	16.34
	23	17.88	16.34	16.26
	29	17.83	16.35	16.27
	30	17.80	16.33	16.25
May	7	17.84	16.46	16.38
	21	17.36	16.26	16.18
	28	17.57	16.61	16.53
June	11	16.88	16.30	16.23
	18	16.90	16.51	16.44
	25	16.57	16.38	16.31
1895				
March	4	17.12	16.43	16.22
	10	17.01	16.18	15.98
April	14	17.69	16.33	16.14
May	6	17.56	16.23	16.07
	12	17.56	16.29	16.12
July	1	16.63	16.39	16.23
	8	16.43	16.39	16.23
				16.246

D is the final value corrected for inclination.

The Equatorial and Polar measures give for the Polar compression of Saturn $\frac{1}{11.42}$.

MEASURES OF THE RING SYSTEM.

OUTER DIAMETER OF OUTER RING.

1894		Observed.	Δ
		"	"
May	6	43.93	40.50
	7	43.52	40.15
	21	42.98	40.26
	28	42.72	40.38
June	11	41.72	40.28
	18	41.01	40.06
	25	40.87	40.39
July	2	39.91	40.26
1895			
March	4	41.97	40.28
	10	42.12	40.06
	24	43.25	40.48
April	7	43.26	40.06
	8	43.09	39.92
	14	43.36	40.03
	15	43.62	40 27
May	6	43.22	39.96
	12	43.14	40.01
June	10	42.04	40.14
	17	42.05	40.59
	24	40.85	39.88
July	1	40.76	40.18
	7	40.12	39.95
	8	40.29	40.19
			40.186

DIAMETER, MIDDLE OF CASSINI DIVISION.

1894		Observed	Δ
		"	"
May	6	37.48	34.55
	7	37.22	34.34
	21	36.50	34.19
	28	36.09	34.12
June	11	35.58	34.35
	18	35.24	34.42
	25	34.80	34.39
1895			
March	4	36.03	34.58
	10	36.24	34.47
	24	37.08	34.70
April	7	37.19	34.44
	8	37.27	34.53
	14	37.41	34.54
	21	37.48	34.50
May	6	37.39	34.55
	12	37.52	34.80
	17	36.29	35.03
	24	35.45	34.61
July	1	35.21	34.71
	7	34.07	34.52
	8	34.55	34.46
			34.517

INNER DIAMETER OF INNER BRIGHT RING.

1894		Observed	Δ
		"	"
May	7	28.11	25.94
	21	27.16	25.44
	28	26.79	25.33
June	11	26.36	25.45
	18	26.20	25.59
	25	25.82	25.52
1895			
March	4	26.85	25.77
	10	26.99	25.67
	24	27.22	25.47
April	7	27.09	25.04
	8	27.49	25.47
	14	27.83	25.69
	21	27.77	25.60
May	6	27.94	25.83
June	17	26.75	25.82
	24	26.44	25.81
July	1	26.18	25.81
	7	25.58	25.47
	8	25.05	25.58
			25.626

INNER DIAMETER OF CRAPE RING.

1895		Observed.	Δ
		"	"
March	4	21.36	20.50
	10	21.57	20.51
	24	21.69	20.30
April	7	22.32	20.67
	8	21.97	20.36

1895		Observed.	Δ
		"	"
	14	22.73	20.98
	21	22.23	20.50
May	12	22.38	20.76
June	17	21.19	20.46
	24	20.87	20.38
July	1	20.68	20.39
			20.528

WIDTH OF CRAPE RING.

1894		Preceding.		Following.	
		Observed.	Δ	Observed.	Δ
		"	"	"	"
April	23	2.42	2.21	..	..
	30	..	..	2.48	2.28
May	6	2.48	2.29	2.51	2.31
	7	2.54	2.34	2.46	2.27
	21	2.29	2.14	2.10	2.00
June	18	2.34	2.29	..	..
	25	2.25	2.22	..	..
July	2	2.41	2.43	..	..
1895					
April	22	2.70	2.49	2.65	2.45
			2.290		2.262

WIDTH OF CASSINI DIVISION.

1894		Observed.	Δ
		"	"
April	23	0.59	0.55
	29	0.69	0.64
	30	0.67	0.63
May	7	0.34	0.31
	21	0.35	0.32
June	11	0.64	0.62
	18	0.62	0.61
	25	0.66	0.65
July	1	0.49	0.49
	2	0.57	0.57
1895			
March	4	0.37	0.35
	10	0.60	0.57
April	22	0.56	0.52
May	12	0.46	0.42
June	24	0.51	0.50
			0.517

From this value of the width of the Cassini division, and the diameter of the middle of that division determined above, the diameters of the inner part of the outer ring, and the outer part of the inner ring, can be obtained.

CENTER CASSINI DIVISION TO NEAREST LIMB OF PLANET.

1894		Preceding		Following	
		Observed	Δ	Observed	Δ
		"	"	"	"
April	23	8.98	8.21	9.13	8.35
	30	8.91	8.18	9.09	8.34
May	7	8.65	7.98	9.11	8.41

1895		Preceding Observed	Δ	Following Observed	Δ
		"	"	"	"
Feb.	4	8.13	8.16	8.18	8.21
	5	8.19	8.20	8.12	8.13
	18	8.52	8.35	8.44	8.27
March	3	8.67	8.33	8.78	8.44
			8.201		8.397

Inner Edge of Inner Bright Ring to Ball.

1894		Preceding. Observed.	Δ	Following. Observed.	Δ
		"	"	"	"
April	23	4.23	3.87	4.13	3.78
May	6	4.14	3.82	4.18	3.85
			3.845		3.815

Outer Edge of Outer Ring to Nearest Limb of Planet.

1894		Preceding. Observed.	Δ	Following. Observed.	Δ
		"	"	"	"
Feb.	25	11.95	11.23	12.05	11.33
	26	11.98	11.24	11.75	10.89
March	11	11.89	11.02	12.08	11.10
	12	12.10	11.17	11.92	11.00
	25	12.45	11.39	12.30	11.26
April	9	12.36	11.27	12.00	11.49
	10	12.23	11.15	12.01	11.50
	23	12.20	11.21	12.46	11.39
	29	12.16	11.15	12.30	11.36
May	6	12.28	11.33	12.04	11.10
	21	11.83	11.08	12.29	11.51
			11.203		11.275

These measure show that the ball is symmetrically placed in the rings and that, during the observations, no measurable eccentricity existed in these rings.

The measures are in accordance with the earlier determinations of the ring system, and show that no observable change has taken place, thus disproving (as had Professor Hall's measures of 1884–1887) Struve's supposition that the rings were measureably closing in on the ball.

No abnormal features were seen either on the ball or on the rings during the observations.

The only complete set of filar micrometer measures that I know of for comparison with this work was made by Professor Hall with the 26-inch at Washington during the years 1884-7. The conditions of instruments and measurement being similar, the two sets should be strictly comparable.

DIFFERENCES ($H - B$).

	″
Equatorial Diameter	− 0.08
Outer Diam. Ring	+ 0.26
In. Diam. Outer Ring	− 0.08
Diam. Center Cassini Division	+ 0.01
Outer Diam. Inner Ring	+ 0.12
Inner Diam. Inner Ring	+ 0.10
Inner Diam. Crape Ring	− 0.01
Width Cassini Division	− 0.10
Mean Difference ($H - B$)	+ 0.026

These are in as satisfactory accord as could possibly be expected in measures of this kind, and do not seem to indicate any change in the past ten years.

The rather large difference for the outer diameter of the Rings may mean some possible change in that element, or, more probable, a slight eccentricity of the outer part of the Ring, though an inspection of my series of measures does not seem to strengthen this latter idea.

Professor Hall did not measure the Polar diameter.

SATURN'S SATELLITE TITAN.

Titan was the only one of the satellites that showed a measurable disc. The following measures were made only when the satellite was well seen. No markings were seen upon it.

DIAMETER OF TITAN.

1894		Observed ″	Δ ″
May	6	0.53	0.49
	7	0.53	0.49
June	18	0.62	0.61
	25	0.75	0.74
July	2	0.60	0.61
1895			
March	10	0.68	0.65
April	14	0.76	0.70
May	12	0.73	0.68
June	3	0.78	0.74
	3	0.75	0.71
	24	0.56	0.55
	24	0.64	0.63
			0.633

URANUS.

The diameters of Uranus were measured during the observations of the four satellites in 1894. Unless the disc could be well seen no measures were attempted. No markings of a definite nature were seen upon the planet.

DIAMETERS OF URANUS.

1894		Polar. Observed.	Δ	Equatorial. Observed.	Δ
		"	"	"	"
April	9	4.46	4.11	4.65	4.30
May	6	4.22	3.88	4.32	3.97
	7	4.07	3.74	4.24	3.90
	21	4.28	3.94	4.50	4.14
	28	4.20	3.88	5.15	4.76
June	11	4.18	3.88	4.34	4.03
	18	4.15	3.87	4.24	3.96
July	8	4.45	4.22	4.39	4.16
	29	3.99	3.85	4.23	4.08
			3.930		4.150

During these observations the disc of the planet was decidedly elliptical.

In 1894 and 1895 observations of the position angle of the apparent equator or major axis of the elliptical disc were made with the following results:

1894.430	25°.27 (14 nights).
1895.338	29 .10 (11 nights).

These observations seem to show that the plane in which the orbits of the satellites lie is inclined 20° or 30° from the plane of the equator of Uranus. The diameter measures were made consistent with the above position of the equator.

NEPTUNE.

This planet was well placed for observation. The diameter measures were made in connection with a long series of position observations of the satellite. Unless the planet was well seen no measures were attempted.

DIAMETER OF NEPTUNE.

1894		Observed.	Δ
		"	"
Nov.	18	2.47	2.38
	19	2.47	2.38
Dec.	31	2.55	2.46
1895			
Jan.	6	2.62	2.54
Feb.	5	2.37	2.31
	17	2.61	2.57
	18	2.29	2.25
	24	2.46	2.43
	25	2.54	2.52
March	4	2.50	2.49
			2.433

The disc of Neptune seemed to be perfectly round in all the observations. No markings were seen upon the planet.

FINAL ADOPTED VALUES FOR THE DIMENSIONS OF THE PLANETS.

Collecting the final results, we have the following values of the dimensions of these planets and satellites. First, in seconds of arc, then in English miles.

		"		
Mercury		6.126	2 transits across Sun	2765 miles
Venus		17.397	15 nights	7826 "
Mars	Equ.	9.673	9 "	4352 "
	Pol.	9.581	11 "	4312 "
Ceres		1.076	23 "	487 "
Pallas		0.675	5 "	304 "
Juno		0.263	1 "	118 "
Vesta		0.540	18 "	243 "

The above diameters in arc are all reduced to the Sun's mean distance = 1.

JUPITER.

	"		
Equatorial Diameter	38.522	24 nights	201196 miles
Polar "	36.412	21 "	83570 "

THE SATELLITES OF JUPITER.

	"		
Satellite I	1.058	8 "	2432 "
II	0.874	8 "	2043 "
III	1.534	10 "	3568 "
IV	1.430	9 "	3345 "

The diameters in arc are reduced to distance 5.20.

The smallness of the Vth Satellite prevents any measures of its diameter, since it is never possible to see its disc. Under all powers it was perfectly stellar. From various considerations however, it doubtless does not much exceed 100 miles in diameter; this would give an angular diameter of 0",04 which is beyond the reach of any telescope.

SATURN.

THE BALL OF SATURN.

	"		
Equatorial Diameter	17.758	21 nights	76470 miles
Polar "	16.216	19 "	69780 "

THE RINGS OF SATURN.

	"		
Outer Diameter Outer Ring	40.186	23 nights	172610 miles
Inner " " "	35.034		150480 "
Center Cassini Division	34.517	21 "	148260 "
Outer Diameter Inner Ring	34.000		145990 "
Inner " " "	25.626	19 "	110070 "
" " Crape "	20.528	11 "	88190 "
Width Cassini Division	0.517	15 "	2220 "
Diameter Satellite Titan	0.633	7 "	2720 "

The values in arc for Saturn are all reduced to distance 9.5389.

URANUS.

	"	
Mean Diameter	**4.040**	**34900 miles**

This is reduced to distance 19.1833.

NEPTUNE.

	"	
Diameter	2.433	32900 miles

This is reduced to distance 30.0551.

It will be seen that these observations make Uranus larger than Neptune, which is contrary to the generally accepted results. I think, however, that the relative values given here will be found to be correct.

The observations, when required, have been corrected for refraction.

In reference to the foregoing measures, I would say that for a long time it had been my desire to determine anew, with the micrometer, the dimensions of the different members of our solar system. When finally the opportunity occurred to do this with the 36-inch of the Lick Observatory, I undertook the work and measured the diameter of every planet, satellite and asteroid that was measurable. This work has been carefully and conscientiously done. Considering the difficulties attending the measures it has required a great deal of patience and labor. The greatest difficulty encountered was that due to the wind, which is a sore trial at Mt. Hamilton in all micrometer work. The free access of wind to the tube of the 36-inch kept it often in constant vibration, so that accurate measures were obtained only by waiting patiently for moments of steadiness of the image. This was extremely trying on the time and nerves of an observer.

The Yerkes Observatory here, has a splendid and eminently successful system of curtains for the observing slit of the 40-inch dome, which were put in by Messrs. Warner & Swasey. They can be raised or lowered at will to shield the telescope from the effects of the wind. These curtains have been carefully tested and the protection they offer the telescope has proved a splendid success. In the few times that we have been permitted to use the 40-inch, the wind on several occasions has been bad and with the slit unprotected the telescope vibrated so much so that the oscillation of the image would have made micrometer observations difficult if not impossible. Drawing the curtain up and thus protecting the tube from the direct impact of the wind, the image at once became beautifully steady and permitted the splendid performance of the driving clock to become at once apparent. There are two of these curtains—one is drawn from above through the zenith and the other is drawn up from the base of the observing slit. The upper one also serves admirably as a

protection from dew except when the observations are near the zenith.

I have had something to say on the subject of wind-breaks of this kind for big telescopes before (see *A. J.* 285, *A.* and *A. P.* June and Oct. 1893) and am glad to see that these ideas, when practically tested, prove that a wind break can be successfully applied to the protection of the great telescopes of today.

So far as I know, Mr. Burnham (A. and A. P. for June 1893) was the first to suggest a wind break of this kind in the early days at Mt. Hamilton.

YERKES OBSERVATORY,
Williams Bay, Wisconsin, 1897, August 20.

THE STUDY OF THE VARIABLE STARS. VIII.

PAUL S. YENDELL.

FOR POPULAR ASTRONOMY

1090 β PERSEI (ALGOL) 3.

The first astronomer whose discussion of Algol's period is of any importance was Wurm, to whom reference has already been made in these papers.

According to Chandler, Wurm, about 1800, determined its value, from sixteen months' observations, as $2^d\ 10^h\ 48^m\ 58^s.69$; afterward, from fifty or sixty minima by various observers, between 1783 and 1818, he deduced the value $2^d\ 20^h\ 48^m\ 58^s.50$. He did not, however, undertake to distinguish whether the period had really shortened in the interval.

Argelander, in the discussion to which reference was made in the first of these papers, put the matter of the change in the period beyond a doubt, but, owing to the insufficiency of the data then available, was unable to develop any satisfactory formula with either secular or periodical terms; he concludes that "we shall have to wait in patience a long time, until later observations shall throw a stronger light upon the progressive change of the period."

Schönfeld, in his memoir, referred to in the last paper, found his observations (1859-1870) well enough represented by a constant period, and gives elements as follows:

1867 Jan. 0^d 11^h $1^m.2$ Paris Mean Time.
$+ 2^d\ 20^h\ 48^m.9$ $(E - 8534)$

The elements in his Second Catalogue are slightly different:

1869 Nov. 9^d 3^h 39^m 34^s Paris Mean Time.
$+ 2^d$ 20^h 48^m $53^s.67$ $(E - 8898)$

being deduced by him from fifty-one minima observed by himself between 1864 and 1873. Says Chandler: "It may be added, that very shortly after this, the period, which for fifteen years had been nearly constant, if not very slowly lengthening, began again to diminish rapidly, and afterwards has again become sensibly constant."

In 1888, Chandler, having gathered together the great number of nearly seven hundred recorded minima of Algol, undertook a definitive discussion of its elements, in a memoir* which in this direction is as truly a classic as Schönfeld's famous memoir on its light-curve. From this huge mass of material, mostly reduced by himself from the original observations, and which alone occupies seven pages of the *Astronomical Journal*, he deduced a law which up to the present remains our best expression for the irregularities of the star's period. "This law," he says "comprises two inequalities—the first having a period, rather uncertainly determined, of 141.3 years, and a co-efficient of 173.3 minutes of time, and the second a period of 37.7 years, and a co-efficient of 18.0 minutes. There is also evidence of a third inequality, with a cycle of 17 years, but its co-efficient of only 3.5 minutes brings its range so nearly within the limits of the observation-errors, that its existence must await further verification."

The formula expressing this law, which has been retained in Chandler's *Third Catalogue* is

$$1888\ \text{Jan.}\ 3^d\ 7^h\ 21^m.5 + 2^d\ 20^h\ 48^m\ 55^s.425\ E + 173^m.3 \sin (1/50\ E + 202°.5) + 18^m.0 \sin (3/40\ E + 203°.25) + 3^m.5 \sin (1/6\ E + 90°.33)$$

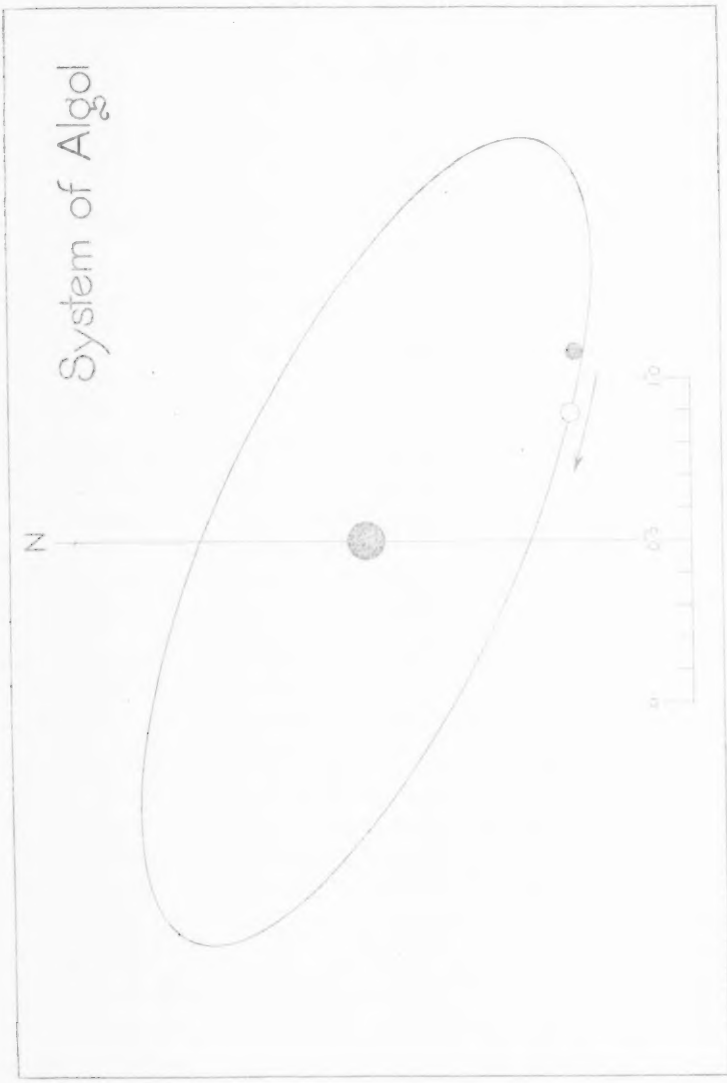
From the above elements, the value of the period is

$$p = 2^d\ 20^h\ 48^m\ 55^s.425 + 3^s.6926 \sin (111°.7 - 1/50\ E) + 1^s.4137 \sin (7°.5 - 3/40\ E) + 0^s.6109 \sin (68°.0 - 1/6\ E)$$

Chandler goes on to say; "The interpretation of the theory thus presented is somewhat as follows. The period of the time of Goodricke's discovery was $2d\ 20^h\ 48^m\ 58^s.0$ It lengthened to $59^s.8$ in 1798, then shortened to $57^s.2$ in 1808, and again lengthened, irregularly, to $59^s.2$ in 1830. Shortly after began a rapid diminution, at the rate of half a second annually, to $54^s.0$ in 1843. After a halt and slower diminution to $52^s.8$ in 1858, an increase set in of a second and a half, to $54^s.4$ in 1866: from

* "On the Period of Algol." *Astronomical Journal*, Vol. VII, p. 165, *et seq.* (1888).

which point the period again fell rapidly to 51ʰ.1 in 1877, and has since remained nearly constant. Should the theory prove to be approximately correct, we are now nearly at the end of the



prolonged interval of general decrease, and may expect in a few years the beginning of an increase, which, with halts and retrogressions, should march to a maximum somewhere late in the next century. We must, however, wait until this general interval of increase has well begun before the cyclical coefficient of the first sine term in the above formula can be found with accuracy."

Up to this date (1888), although our knowledge of the law of the star's period had been carried to a fairly satisfactory point, we were still practically in the dark as to the cause of its peculiar light-variations.

Goodricke, it is true, early suspected them to be due to the interposition of an opaque body, cutting off a part of the light, and presumably revolving as a planet about Algol. This, though recognised as plausible, was not at that time susceptible of proof. Astronomers continued to puzzle over the probable cause of the change, and various suggestions, all, from the extremely regular character of the variation, attributing it to revolution of some sort, were advanced.

Herschel suggested that the existence of spots similar to those on the sun, might, in connection with the probable rotation of the star upon its axis, account for variations of any and all kinds; and this idea, in a more or less modified form, was afterward taken up by Pickering.

Maupertuis suggested that the variable stars might be exceedingly flattened spheroids, and the variation accounted for by a large nutation of the axis of revolution.

Pickering developed from this hypothesis the idea of spheroids of revolution of various forms, and of ellipsoids, revolving so as to present various projections to the observer.

The satellite theory was objected to on the ground that the observed light-curves were in most cases not entirely symmetrical. This, however, ought not to have discredited it, for it is conceivable that other causes of change might exist, which, combined with the rotation, might produce the observed phenomena.

On the whole, the supposition of some cause connected with the star's axial rotation seemed the most tenable hypothesis, until, on 1889 Nov. 28, Dr. Auwers presented to the Berlin Academy of Sciences the results of certain spectrographic observations, made at Potsdam in 1888 and 1889 by Vogel and Scheiner. These observations showed that in every case Algol recedes from the Sun before a minimum, and approaches it after a minimum. This was proved by six different plates, taken, three about the beginning, and three near the end, of the year 1889, which afforded completely accordant results.

The motion per second indicated was:

Before Minimum + 24.4 miles. After Minimum − 28.5 miles.

Dr. Auwers said "the hypothesis that the variation of Algol's light is to be attributed to eclipse by a dark companion revolving around it now receives strong support again from these observations.

The motion of revolution of the principal star may, from the mean of the six measures, be assumed as 26.2 miles per second. Furthermore, the assumption of a circular orbit, described with this velocity, gives, when combined with the period of variation, an arrangement of the system somewhat thus:

Diameter of Principal star	1,047,000	miles
" " Dark companion	821,470	"
Distance of Centres	3,231,000	"
Orbital Velocity of Companion	55.2	"

Masses of the two bodies 4/9 and 2/9 the Sun's mass.

So that Goodricke's original hypothesis was right after all.

In view of the character of the star's light curve, shown in the last paper, it is to be remarked here that the plane of the orbit must be slightly inclined to the line of sight, so that the disc of the eclipsing body is at least tangent to the limb of the bright star, if it do not slightly overlap it, as it will be seen upon a moment's consideration that a central passage of the dark star would result in an interval of 44 minutes of constant light at the minimum, similar to that observed in U Cephei and other stars. which is cetainly not the case. Assuming Auwer's figures to represent the actual facts, an inclination of 7° would account for the character of the observed light-curve.

Two noteworthy attempts have been made to account for the long inequality in Algol's period, by Chandler and Tisserand. The former suggests that the star and its companion revolve together around a third body, dark like the companion, in an orbit whose size is about the same as that of Uranus about the Sun. The plane of this orbit is inclined about 20° to our line of vision. "Algol transited the plane passing through the centre of gravity perpendicular to the line of vision about 1804 going outward, and in 1869 coming inward. Calling the first point the ascending node, its position angle, reckoned in the ordinary way, is about 65°. The orbit is sensibly circular, or of very moderate eccentricity. The longest diameter of the projected ellipse, measured against the face of the sky, is 2″.7. The present position angle of the unknown body from Algol is 32°, and its distance is 0″.74."

Tisserand, however, doubted the existence of such an arrangement, and considered the irregularity equally well accounted for by the assumption that the orbit of the companion was of considerable eccentricity, and that a progression of the line of the apsides, which also would account for the long inequality, existed.

This hypothesis, which he considered simpler than that of Chandler, still calls for the presence of a third body in the system.

It is possible to apply a test which shall discriminate between these two hypotheses, by carefully observing the beginnings and ends of the minima; if Tisserand's solution be correct, the length of time occupied by the light-variation must be changing, and a long and careful series of observations would demonstrate or disprove this.

Chandler has applied his hypothesis to two other stars of this type, in whose cases a similar long inequality exists, U Cephei and U Ophiuchi. And he considers that he finds in their observed irregularities of proper motion, something very like ocular proof of the existence of conditions similar to those detailed above.

His account of these may be found in the *Astronomical Journal*, Vol. XIII, p. 45.

From the peculiar character of the variations of this class of stars, they are very difficult to detect, indeed they are always first happened upon by chance, and often must be followed up with endless patience for a very long time before the fact of their variation and its type can be proved. I have now on my observing list several such stars, some of which have been on hand for several years, without proof having been obtained.

There are now seventeen variables of this type, known as follows:

		Position 1900						Period			Light-range	
		h	m	s		°	′	d	h	m	s	M M
320	U Cephei R. A	0	53	23	Dec.	+81	20.2	2	11	49	37.85 *	7.1 — 9.2
1090	β Persei	3	1	40		+40	34.2	2	20	48	55.425*	2.3 — 3.5
1411	λ Tauri	3	55	8		+12	12.5	3	22	52.2	*	3.4 — 4.2
2610	R Canis Majoris	7	14	56		−16	12.4	1	3	15	46.0	5.9 — 6.7
3055	X Carinae	8	9	7		−58	53.2	0	12	59	31.5	7.8 — 8.6
3109	S Cancri	8	38	14		+19	23.6	9	11	37	45	8.2 — 9.8
3407	S Antliae	9	27	56		−28	11.2	0	7	46	48.0	6.7 — 7.3
3416	S Velorum	9	29	27		−44	45.9	5	22	24	35	7.8 — 9.3
5144	Y Boötis	14	17	22		+20	15.8	2.6				8.0 — 8.6
5374	β Librae	14	55	38		−8	7.3	2	7	51	22.8	5.0 — 6.2
5484	U Coronae	15	14	7		+32	0.8	3	10	51	12.4	7.5 — 8.9
5949	R Arae	16	31	26		−56	47.6	4	10	12.7		6.9 — 8.0
6189	U Ophiuchi	17	11	27		+1	19.3	0	20	7	42.56*	6.0 — 6.7
6442	Z Herculis	17	53	56		+15	8.8	3	23	49.545		7.1 — 8.0
6546	R S Sagittarii	18	10	59		−34	8.5	2	9	58.6		6.4 — 7.5
7399	W Delphini	20	33	7		+17	55.9	4	19	21.2		9.5 — < 12
7488	Y Cygni	20	48	4		+34	17.0	Even	11	57	27.6	7.1 — 2.9
								Odd	11	57	15.2	

NOTES.

320 Halts at minimum about 2 hours.

3109 Curve similar to 320.

3407 Pickering says not Algol-type, but similar to U. Pegasi. My observations not decisive.

3416 Curve similar to 329.
5374 Type not quite certain. Variation possibly intermittent.
6442 Double period with two unequal minima. Pickering has failed to derive the secondary minima photometrically.
7309 Curve probably similar to 329.
7488 Double period. Brightness at minimum, variable. * Periodic inequality.

ROCHESTER, MASS., 1897, August 7.

DRAWINGS OF JUPITER'S THIRD SATELLITE.

A. E. DOUGLASS.

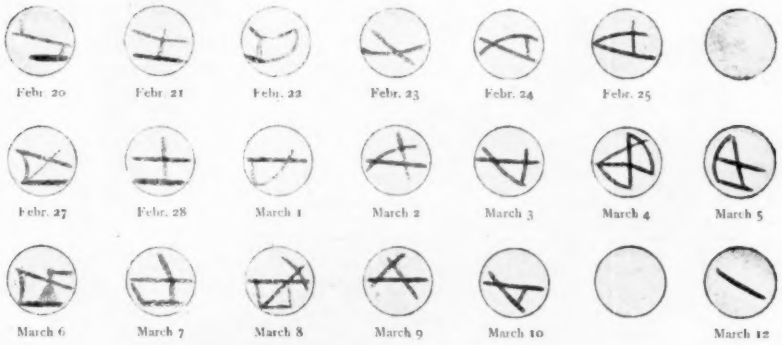
The accompanying drawings of detail on the third satellite of Jupiter, were made through the 24 inch Clark glass of the Lowell Observatory during parts of February and March, 1897. Beginning in the latter part of January occasional drawings were made, but the atmosphere was not perfectly steady and there always seemed to be an element of uncertainty in the markings suspected. On February 20th, after making a few drawings of that uncertain kind, an interval of extremely good seeing revealed the "Great Northern Belt" in longitude 260° to 20°, with perfect distinctness and definition, indicating the character of the markings to be expected. On the following night the vertical line in longitude 0° was seen, and on the third night this vertical line was seen to have moved towards the left (terrestrial west) giving at once a rough estimate of the period of rotation.

During the first week insufficient care was taken with the orientation; so it is probable that certain early drawings are slightly in error in that respect, and allowance has been made for that in constructing the map. From February 20th to March 1st the drawings were compared and carefully studied from night to night, but, beginning on March 2d and continuing through this series, no comparisons were made with previous observations, in order to make each night's work absolutely independent.

The smaller series of eight drawings shows several attempts to discover signs of surface movement within the three to five hours of continuous observation. None could be detected and the rotation, therefore, is not approximately twenty-four hours; it must therefore be very closely one week, as shown by the larger series of sketches, or nearly the same as this satellite's period of revolution about Jupiter. Recent observations (Flagstaff, May 14th and subsequent dates) not only confirm the map but indicate a period of rotation of $7^d\ 5^h.1 \pm 1^h.2$, or one hour longer than its period about its primary. This difference of one hour, it will be

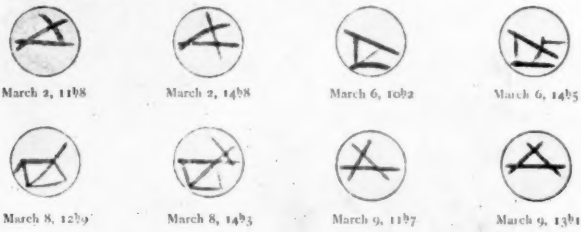
PLATE XXII.

Drawings from which map was made, showing that period is either 7^d or 21^h, direct motion, or 27^h retrograde.

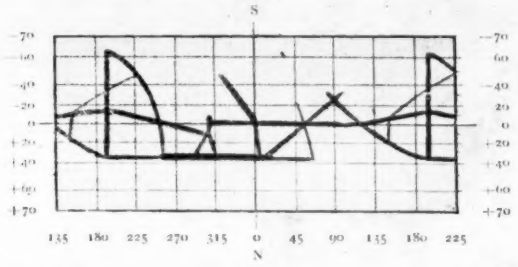


(No observations on February 26 or March 11).

Drawings showing that period is not approximately 24 hours and must therefore be 7^d, direct motion.



Map, on Mercator's projection, reduced from globe.



Lowell Observatory, Mexico, 1897. *A. E. Douglass*, Observer.

Drawings of Jupiter's Third Satillite.

observed, is less than the probable error. An ephemeris will be published in a subsequent article, but for the present, it is sufficient to state that all drawings of detail made from January to July, 1897, can be identified by the inferior conjunction with Jupiter, during which the detail in the third column of the larger collection of drawings, is visible.

The lines thus discovered on this satellite, are extremely narrow. Recent observations with a power of 750 and good seeing have led me to this view, the maximum width being estimated at less than 0″.1 or 200 miles. Judging by the obliteration of lines while seeing is growing worse it seems probable that the most conspicuous lines are not wider than the others but are intrinsically darker.

In order to prepare a map, a small ball of wood was painted white, graduated and mounted in a pasteboard circle so that it could represent the satellite. Each drawing was then carefully placed upon this globe in its proper position, and the Mercator's projection plotted off from the resulting combination. The only lack of agreement occurred between longitudes 135° and 180° and observations now going on are supplying the needed data.

Work was carried on upon the other satellites during the same period of good seeing in Mexico. Drawings were made of the Fourth which indicate that it is covered by a series of markings similar to those found on the Third. Its period of rotation is also probably nearly equal to its period of revolution about Jupiter. Markings were seen on the second and first satellites and the first was seen to be most remarkably elongated and to vary in its elongation, as Professor W. H. Pickering was the first to discover. Observations are now being carried on to verify, correct and enlarge the results already obtained.—*Astronomische Nachrichten, Band 143.*

LOWELL OBSERVATORY, Flagstaff, Arizona, U. S. A.
May 23, 1897.

PROBLEM OF SOLAR MOTION.

MARY W. WHITNEY.

FOR POPULAR ASTRONOMY.

There is no question of greater importance to the astronomical student or of greater interest to the general reader of science than the question of the translation of the solar system through space. A century ago the stars were practically regarded as fixed points on the celestial sphere. We still speak of them

as fixed stars, but we do not doubt that they all move, though the amount and direction of motion are known but in a comparatively few cases. The determination of this motion, called proper motion, is a delicate matter, and calls for the best appliances and the most careful observations. It also calls for a long lapse of time, the longer the better. The changes in position of the stars are so very slow that a few years, twenty or thirty, are generally insufficient to give results that can be depended upon. If a star moves 50″ in a century, it is regarded as a swift traveller. About a hundred are now known to move more rapidly still, from 100″ to 700″ in a century, but the great body of stars that build up the constellations familiar to us move far more slowly, and their shiftings would not make any perceptible differences to the untrained eye after the lapse of centuries. The constellations present, from our terrestrial point of view, the same general appearance that they did to the early Chaldean or Egyptian astronomers. Yet constant changes are going on and in these changes lies the answer to the question: Whither is the Sun and its revolving planets tending in space?

This proper motion of a star may have two causes. It may result from its own motion, or it may result from our motion as observers, producing the well known parallactic effect. If it is caused by our change of position then must the motion be that of the Sun carrying with it the Earth. Without shadow of doubt, the star's proper motion is the result of both these causes. The short arc that the star describes in a century is produced partly by its own motion and partly by the motion of the Sun. The first is called peculiar proper motion or absolute motion, and the second parallactic proper motion. But how are these to be separated? That is plainly a difficult problem, and astronomers are but as yet on the threshold of it. How can these two effects be distinguished and how in such involved motions can we decide what part is to be attributed to the Sun's progress along its unknown orbit? Or, in other words, stating the question as it stands today: How decide from these combined and complicated changes of position the direction and amount of the solar motion?

It is plain that if the stars were absolutely fixed, the parallactic effect would be such, that each star would appear to move backward upon a great circle passing through the point in the sky, toward which the Sun is advancing. This point is called the apex of the Sun's way. Sir William Herschel made use of this simple principle, when in 1783 he gave the first determination of

this apex of solar motion. He selected a small number of stars whose proper motions were best known, and drew upon a globe the great circles of which these proper motions were small arcs. Their intersections did not, of course, fall at one point, but they were quite close together, and from their positions he decided that the point toward which the Sun is tending lies near λ Herculis. This was a rough method, but it gave a first result, and it was a remarkably good one as judged by more recent investigations. But how can the problem be treated more exhaustively?

A second principle of great scientific value leads to at least an approximate answer to this question. This is a principle based on the theory of probabilities and can be simply stated as follows. Suppose a large number of values, subject to variations on either side of a mean value, and suppose these variations bound by no common law. Then, if a sufficiently large number of such values are taken into consideration, it will be found that the variations on either side of the mean value will counterbalance one another. If, then, we regard the absolute motions of the stars as subject to no common law, i.e., if we suppose the stars to be pursuing their courses independent of any common centres of gravity, and if a very large number of proper motions are taken together, it would follow from this principle, that in the aggregate the peculiar proper motions would cancel one another, and the mean result would be unaffected by them and would give only the parallactic effect of solar translation. This method of treatment, based upon the theory of probability, is called the method of "Least Squares", and is of very wide application, but for our present purpose this brief reference must suffice.

From the time of Herschel's first determination till 1859, the process of investigation, making use of the method of Least Squares, was as follows. Some previously obtained apex was assumed as approximately correct. As many well ascertained proper motions as possible were secured. For all these stars the theoretical directions in which they would move on the basis of the assumed apex and of parallactic effect alone were computed. The differences between these computed directions, and the directions obtained from the observations gave a series of values, which being treated by the method of Least Squares would lead to the best possible determination of the apex under the given conditions. Argelander in 1837 employed in his investigation 390 stars, whose proper motions he had obtained by comparing his own observations for 1830 with Bradley's for 1755.

In 1859, Sir George Airy introduced a somewhat different method of dealing with this problem. He held that the assumption of an approximate apex on the celestial sphere was open to too many sources of error and should be abandoned. He introduced in place of this a treatment by rectangular coördinates in space, which involves no assumption of the values to be obtained, which, in every case, are the right ascension and declination of the apex. In this method, however, an assumption must be made regarding distance. Airy made magnitude the basis of his hypothesis, assuming a first magnitude star to be nearest to us, and making suppositions regarding the relative distances of the different magnitudes. The resulting apex fell not far from those hitherto obtained by the first method, all of them within the constellation Hercules. But Airy's method is considered more exact and has quite superseded the former. The unit of distance is no longer made to depend on magnitude, since experience has shown that proper motion rather than magnitude is the better test of distance. Professor Boss takes as his unit of distance the mean distance of all the stars involved in his discussion.

In 1887 Struve published an exhaustive investigation of this problem, making use of 2,509 stars. Auwers had made a new reduction of Bradley's observations of these stars (1755) and this together with the St. Petersburg catalogue of 1855 afforded excellent material for the derivation of trustworthy proper motions.

In all the more recent investigations, the stars employed have been taken in groups arranged according to amount of proper motion. If the various results obtained in the different groups agree well, then the hypotheses upon which the discussion is based are justified. If they do not agree, some further hypothesis may be needed and the character of the results may suggest an additional hypothesis. Such a discordance has presented itself and has led to the supposition that the nearer stars are bound together under some common law, and that their absolute motions cannot be rightly regarded as of the nature of accidental errors in the least square treatment. Some of the later investigators, Stumpe, Porter and others have introduced into their discussion an additional hypothesis, as, for instance, the common revolution of the stars in the plane of the Milky Way. The results thus far have been of a negative character, neither confirming nor refuting the hypothesis. But, as Dr. Stumpe remarks, the stars involved have not been sufficiently well distributed to justify a definite conclusion. Comparatively few southern stars have been

long enough observed to give trustworthy, proper motions and the correct solution of this large problem must needs lie in a complete aggregation of all stars, north and south. Therefore the longer we wait, the better result may we expect, since the lists of well observed stars are gaining in number every year. The work of the *Astronomische Gesellschatt* in producing its already celebrated star catalogues, is affording rich material for the future discussion of this cosmic question.

The many determinations that have thus far been made of the apex of the Sun's way agree remarkably well considering the complex nature of the problem. Yet they cover a considerable area, as is shown in a drawing in Proctor's Old and New Astronomy, p. 759. The question naturally arises, as the time now elapsed since the first investigation is a century, are these divergencies of position for the apex wholly due to the errors involved, or may an actual change of apex be suggested, if not inferred? A change of apex means a curved path, and whatever the immediate data or inferences, we can hardly question that the solar system is moving, not in a straight line, but in a curve. Still it is certainly too early to decide what the trend of that curve is. Our investigation is immature and the curve must be one of an immense sweep. We can face the constellation Hercules on any clear evening and know that with hardly a doubt we are looking out into that region of space which in coming time will be the scene of solar activities and planetary experiences. But which way this vast vehicle will bear, whether toward the great galactic highway or from it, we cannot yet foresee.

Yet another method of dealing with this problem is offered by the spectroscope, and herein is contained a most hopeful indication of future progress. Motion in the line of sight is shown by the displacement of lines in the spectrum of a star, whether the motion is that of the star or of the observer. The spectral lines of stars lying about the apex will be displaced in one direction, toward the violet end of the spectrum, of those lying about the ante-apex, in the opposite direction and to the same amount so far as solar motion is concerned. Stars lying at right angles to the solar advance will present no displacement of lines from this cause, and the lines of those holding intermediate positions will be displaced by amounts depending upon their angular distances from the apices. The absolute motions come in here as before, but the same principle can be applied regarding their aggregate effects, if no common centers of gravity are supposed to control. The material for this most suggestive treatment is yet in the

making, and only preliminary discussions have been published. M. Homann made such a tentative reduction from 49 of the brightest stars which had been spectroscopically studied by Professor Vogel, and he obtained an apex quite out of the constellation Hercules, near the well known star 61 Cygni. Professor Vogel himself has since tried his hand with a larger number of stars and also obtains a point considerably removed from those deduced by the astronomical method. But it would be unwise to conclude that the more extensive investigations which will follow before many years will lead to like divergences.

Thus far we have spoken of direction of solar motion only. But what about velocity of motion? How fast is the Sun moving toward this goal in the region of Hercules? Here the astronomical method, even with its larger accumulation of data, cannot give so good an answer as the spectroscopic, because the astronomical determination of rate presupposes a knowledge of the distances of the stars and our information on this point is very meagre. The several determinations of velocity by the method of position present a large range, extending from five to 150 miles a second. The spectroscopic method is independent of distance, and therefore affords a surer way of meeting this second interesting question. Although, as stated above, but a few solutions have yet been attempted. Professor Vogel believes that the results may be relied upon with considerable confidence. Homann obtained 15 miles per second and Vogel less than three miles. Undoubtedly the Sun ranks as a very moderate traveller through the realms of space. It is making a slow majestic sweep, and is allowing to successive generations of men ample time to grow familiar with that portion of the spatial universe through which they move. We know that many stars have a velocity per second reaching up into the hundreds. This to be sure, is the full proper motion, not the absolute alone, but 1830 Groombridge and Arcturus must be speeding very rapidly indeed, quite independent of the apparent velocity which our relatively slow progress transfers to them.

This voyage of the whole solar system through unknown regions of space affords unlimited play to the imagination, whether literary or scientific. The course of the Earth in its yearly revolution around the Sun is a vast one indeed. Its continual repetition, however, diminishes the awe with which the mind contemplates it. But here is a journey unknown in character, whose present direction we know something about, but whose relations to the universe at large are altogether a mystery. Does the Sun

belong to a group of stars and is that motion we are now considering only a secondary or interstitial motion, corresponding to the Earth's orbit about the Sun? Is the whole group pursuing a vastly larger orbit, of which we have at present no conception? Where lies the centre of the solar motion, whether that motion is primary or secondary? What chances lie before us on this unknown journey? Is all space alike in its conditions and proportions? Does the coming of comets within our range depend upon the regions of space through which the solar system is passing? Is it not probable that at times we sweep through portions richer in those aggregated masses which make up the body of a comet? Many questions like these stir the fancy and stimulate the imagination.

THEORETICAL CAUSE OF THE FAILURE OF PARABOLIC REFLECTING TELESCOPES OF LARGE ANGULAR APERTURES.

J. M. SCHAEBERLE

For Popular Astronomy.

The readers of "Popular Astronomy" will be interested to learn that the much discussed question as to the relative merits of refracting and reflecting telescopes has, for purely theoretical reasons, assumed a most curious and definite phase through my discovery of a remarkably large optical error introduced in the images formed by a parabolic reflector. This error alone, aside from all other optical defects—due to bad seeing, peculiar optical properties of light and the like—makes it geometrically, and hence also physically, impossible for the different concentric surface-zones of a theoretically perfect paraboloid of revolution to form equal images of any celestial area subtending a measurable angle.

The *cause* of the error may be stated in a single sentence. *The focus of any paraboloid of revolution is not at the center of curvature of the surface;* a fact well known to every astronomer, every optician, and to every student of the conic sections.

To illustrate just why the non-coincidence of the focus with the center of curvature plays such an important and mischievous part let us suppose that a small circular disk, placed in the focal

plane of a paraboloid of revolution concentric with the optical axis, is viewed from different points in the surface of the paraboloid. The form of the disk will not only appear to vary from a circle, on the optical axis, to an ellipse of increasing eccentricity as the distance of the eye from the optical axis increases, but *the angular diameter of both axes of this ellipse will decrease owing to the increasing distance of the eye from the focal point.*

It therefore follows that when the angle at any and every point in the mirror's surface is constant, (as is the case for rays of light coming from any two neighboring points, on the celestial sphere, which are reflected by the mirror) the *linear* distance between the focal images of these two points as formed by reflection from different areas along any radius of the mirror will vary from a mininum for the reflecting area on the optical axis to a maximum for the area most distant from this axis. These overlapping images of different diameters form a single *blurred* image.

As the angular amount of the blurring—at the same angular distance of the image from the optical axis—in different telescopes depends simply upon the ratio of aperture to focal length, each instrument has, what I shall call, its *blurring factor.* This constant for a particular telescope is given by the expression

$$\text{Blurring Factor} = \frac{1}{\cos v \,.\, \cos^2 \frac{1}{2} v} \qquad (1)$$

In which $2 \,.\, v$ is the angular aperture of the parabolic mirror whose focal distance is F and whose diameter is $2 \,.\, R$.

v can be found from the equation

$$\frac{F}{R} = \frac{\cos^2 \frac{1}{2} v}{\sin v} \qquad (2)$$

The second member of equation (1) is equal to the maximum angular distance of any point of the image from the optical axis divided by the minimum angular distance of the same point of the image from the optical axis (as formed by the outermost and by the central portions of the mirror respectively).

For the derivation of formulas (1) and (2) the reader is referred to a paper of mine in a forthcoming number of the "*Astronomical Journal.*"

The amount of the blurring (caused by overlapping images) for some of the more modern reflectors is given in the following ta-

ble the distances of the image from the optical axis being assumed to be 60″ and 20′ respectively.

Reflector.	Diameter of Reflector = 2R	Focal Length = F	Ratio of Focal Length to Aperture.	Blurring Factor.	Amount of Blurring at 60″ and 20′ from Optical Axis.	
					60″	20″
	Feet.	Feet.				
Lord Ross	6.0	55.0	9.6	1.0022	0.13	2.6
Common	5.0	27.0	5.4	1.0077	0.46	9.2
Lassell	4.0	37.0	9.7	1.0022	0.13	2.6
Melbourne	4.0	28.0	7.0	1.0039	0.23	4.4
Paris	3.9	23.4	6.0	1.0051	0.31	6.1
Crossley	3.0	17.3	5.8	1.0057	0.34	6.8
Draper	2.4	13.0	5.4	1.0064	0.38	7.7
Lassell	2.0	20.0	10.0	1.0019	0.11	2.3
Roberts	1.7	8.2	4.8	1.0078	0.47	9.4
Common	1.7	3.7	2.2	1.0404	2.42	48.5
Schæberle	1.5	12.3	8.2	1.0028	0.17	3.2
Draper	1.3	13.0	10.0	1.0019	0.11	2.3
Hypothetical	—	—	14.0	1.0009	0.05	1.1
"	—	—	18.0	1.0005	0.03	0.6
"	—	—	22.0	1.0004	0.02	0.5

An inspection of the figures given in the last two colums at once makes it evident that even for, say, the planets Jupiter and Saturn on the optical axis, and observed under the best possible conditions, the blurring of the outlines will be sensible in every one of the above mentioned telescopes.

As it would be nothing unusual for the center of the field of view to be several minutes of arc from the optical axis without the observer being aware of the fact, the peculiar variations in the performance of the mirror (usually attributed to flexure) is easily accounted for, since a slight shifting of the optical axis with reference to the field of view would cause large variations in the defining power of the mirror, aside from distortional effects as ordinarily considered.

The ratio of focal length to aperture should not be less than, say 14 to 1 if good definition is desired, and even then it is essential that the center of the field of view shall coincide with the optical axis and all observations made within a few seconds of arc from this axis.

The reader will doubtless be amazed that errors of such magnitude should have escaped the attention of astronomers from the days of Newton to the present time, especially so as the comparisons between visual observations made with the refracting and reflecting telescopes have indicated that there was something

wrong in the images formed by the latter instrument. For the examination of nebulous objects, having no sharp boundaries, the reflector of large angular aperture will continue to be of invaluable service to astronomy both visually and photographically.

LICK OBSERVATORY, University of California,
Sept. 17, 1997.

ON THE ADJUSTMENT OF THE SPECTSOSCOPE.*

The following directions are given in response to the requests of a number of the readers of this book:†

A. The first step is to focus the view-telescope approximately. Remove it from the spectroscope, and, turning it toward the sky, adjust the eye-piece until the wires of the micrometer, if there is one, are perfectly distinct; then pointing to some *distant* object, move the micrometer itself in or out until the object is distinct at the same time with the wires. If there is no micrometer, it is necessary only to set the eye-piece to distinct vision of the remote object. It is best to make a permanent mark of some kind on the tube by which the telescope can be again focused at once if it happens to be disturbed.

B. To focus the collimator. Replace the view-telescope on the spectroscope, and if the construction of the instrument permits, remove the prisms or grating and set the telescope so as to look directly into the collimator. Bring the collimator-slit exactly to the center of the field of view and close it so as to make it very narrow. Now, being careful not to disturb the focus of the telescope, slide in or out the tube that carries the slit until the slit appears in the telescope clear and sharp as a fine, colorless line of light. It may be necessary to illuminate the slit by putting a piece of white paper before it, or in some other way.

It frequently happens that the instrument is so constructed that the telescope cannot be pointed into the collimator. In that case we can proceed as follows if the spectroscope has a *grating:* Turn the grating until the reflected image of the slit is thrown into the view-telescope, and then focus the collimator as before

* From supplementary notes prepared by Professor C. A. Young which are to be appended to the next impression of the new edition of "The Sun." We are favored by Professor Young and also the publishers, Messrs D. Appleton & Company, in being permitted to use this matter in advance of regular publication. It is supplementary to page 74 in the new and revised edition of "The Sun" for 1895.

† "The Sun."

directed. (In order to get the image of the slit into the center of the field of view it may be necessary to touch the screws which adjust the inclination of the grating.) If the grating is truly flat, this method will give just as good results as the one first mentioned, and the gratings now obtainable are generally unexceptionable in this particular.

With a prism spectroscope the best that can usually be done is simply to focus the collimator by sliding in or out the slit-carrier until the lines of the spectrum are sharp without touching the focus of the view-telescope. If, however, the prism surfaces are not perfectly flat, as often happens, no satisfactory result can be obtained in this way, and the prisms are unfit for *prominence or sun-spot observations*, although they may answer perfectly for some kinds of laboratory work.

C. Make the slit parallel to the lines of the grating or the edges of the prisms by twisting the tube that carries it until the spectrum-lines are perpendicular to the edges of the spectrum; this is usually done at the time when the collimator is focused.

D. To make the lines of the grating perpendicular to the plane which contains the optical axes of the view-telescope and collimator. If the adjustment happens to be perfect, then, on turning the grating, the spectra will travel *straight* across the field of view and without either *rising or falling*.

If the spectra run straight, but rise on one side of the slit image and fall on the other as the grating is turned, the fault is corrected by raising one edge of the grating (so as to rotate it slightly in its own plane) by means of the adjusting screws. If the spectra run in a curve, it shows that the plane of the grating is not parallel to the axis of rotation and the top of the grating must be inclined a little one way or the other. It is likely to require several trials to get both adjustments perfect, as touching one is apt to disturb the other. In spectroscopes with prisms the maker is supposed to have attended to the corresponding adjustment. If he has not done so, it is a rather serious job to make it correctly by slightly tipping the prisms, and it would take too much time to describe the method.

E. To adjust *accurately* the focus of both view-telescope and collimator for a special ray of the spectrum. (The focus differs somewhat for the different colors.) Suppose the C-line is in question: Turn the grating so as to bring into the field of view of the view-telescope the C-line in the spectrum of the second order on the *more dispersive* side of the slit-image. (This spectrum has the *blue end* between the observer and the collimator as he puts his

eye to the eye-piece.) Probably he will find that the line is not quite sharp; if so, make it sharp by focusing *the collimator* without touching the telescope-focus as determined on a distant object. Next turn the grating so as to bring in the second order *C* in the *less dispersed* spectrum on the other side of the slit-image. The telescope will be now perhaps perceptibly out of focus; if so, focus *the telescope* this time, leaving the collimator undisturbed. Then go back again to the more dispersive side and see if the C-line is still in focus; if not, readjust the *collimator*-focus again. It will need only a touch. Of course, if found necessary, a third approximation can be made in the same way. Always focus the *collimator* on the *more dispersed* spectrum and the telescope on the less dispersed, alternating back and forth until the adjustment becomes perfect.

F. To adjust the slit to the focal plane of the equatorial to which the spectroscope is attached. Take out the eye-piece of the equatorial, turn the spectroscope around until the slit lies nearly north and south, and direct the instrument to the Sun, pointing it so that the northern or southern edge of the Sun's image lies across the slit, nearly in the middle. Use a dark glass in looking at the image, otherwise the eye will be dazzled and lose much of of its sensitiveness. Move the whole spectroscope nearer to or farther from the object-glass of the equatorial until the edge of the image appears to be sharp on the slit-plate; this will give an approximate adjustment. Now look into the spectroscope and bring the C-line to the middle of the field. The spectrum will be divided lengthwise into two halves, one very bright—the spectrum of the Sun itself—the other fainter—the spectrum of our own illuminated atmosphere. Focus the view-telescope very carefully upon the *dust lines* in the spectrum (which are always more than sufficiently abundant), and see if then the dividing boundary between the two halves of the spectrum is also perfectly sharp. If not, correct the approximate adjustment slightly until this condition is fulfilled. This last adjustment can be made satisfactorily only when the air is very steady, and once obtained, permanent marks should be made which will enable it to be recovered if disturbed. Moreover the adjustment will be different for the different rays of the spectrum (see page 73, "The Sun"). The focal length of an ordinary achromatic object-glass is shortest for rays between *D* and *E*, is a little longer for *C* and *F*, and about the same for both, and is considerably longer for the indigo and violet. In a telescope with a focal length of a dozen feet the difference between *E* and *H* is fully three-quarters of an inch.

It is perhaps worth noting that the best thing with which to clear the dust from the slit, so far as the author's experience goes, is a piece of soft white pine shaped like a tooth-pick; almost any other kind of wood leaves shreds in the slit-jaws.

EVENINGS WITH THE STARS.

MARY PROCTOR.

FOR POPULAR ASTRONOMY.

During the month of October, we find the seven stars of the Dipper, low down, between north and northwest, the Pointers on the right nearly due north. They direct us to the Pole Star. Between the Pointers and the Pole Star we find the tip of the Dragon's tail; then passing round the Little Bear with the Dragon's long train of third magnitude stars, we come, after a bend, to the Dragon's head, with the two bright eyes, *Alpha* and *Beta*—(part of the Dragon's nose has been borrowed by Hercules). These two stars are almost exactly midway between the horizon and the point overhead, and nearly northwest. King Cepheus lies between the point overhead and the Little Bear.

Low down in the northwest we find the head of the Herdsman (Boötes). The Crown (*Corona Borealis*), which no one can mistake, lies on his left; and close by is the setting head of the Serpent. Above these three groups we see—Hercules the Kneeler—his head at *Alpha*, his upraised club at *Gamma*. Above the head of Hercules we find the Lyre, with the bright star Vega; and above that the Swan. Passing southward, we see the Serpent-Holder (*Ophiucus*) beyond whom lies the Serpent's tail; a most inconvenient arrangement as the Serpent is divided into two parts. Almost exactly southeast, and low down, are the stars of the Archer, (*Sagittarius*); while above in the mid-sky, we see the Eagle (*Aquila*), with the bright Altair. Note the neat little constellation of the Dolphin (*Delphinus*), close by. Due south is the Crane (*Grus*); above it the Southern Fish with the bright star Fomalhaut. Above that the Sea Goat (*Capricornus*), and on the left of this the Water Bearer (*Aquarius*); one can recognize his water pitcher, marked by the stars, *Beta*, *Gamma* and *Alpha*. Toward the west, high up, is the Winged Horse (*Pegasus*); which is upside down just now. Below lies the Whale (*Cetus*), or rather the Sea Monster. The star Omicron of this constellation is called Mira. It is a wonderful variable star. The Fishes (*Pisces*) may be seen between the Whale and Pegasus. Few constellations have suffered more than Pisces by the breaking up of star groups. The Fishes themselves are now lost in Andromeda and Pegasus.

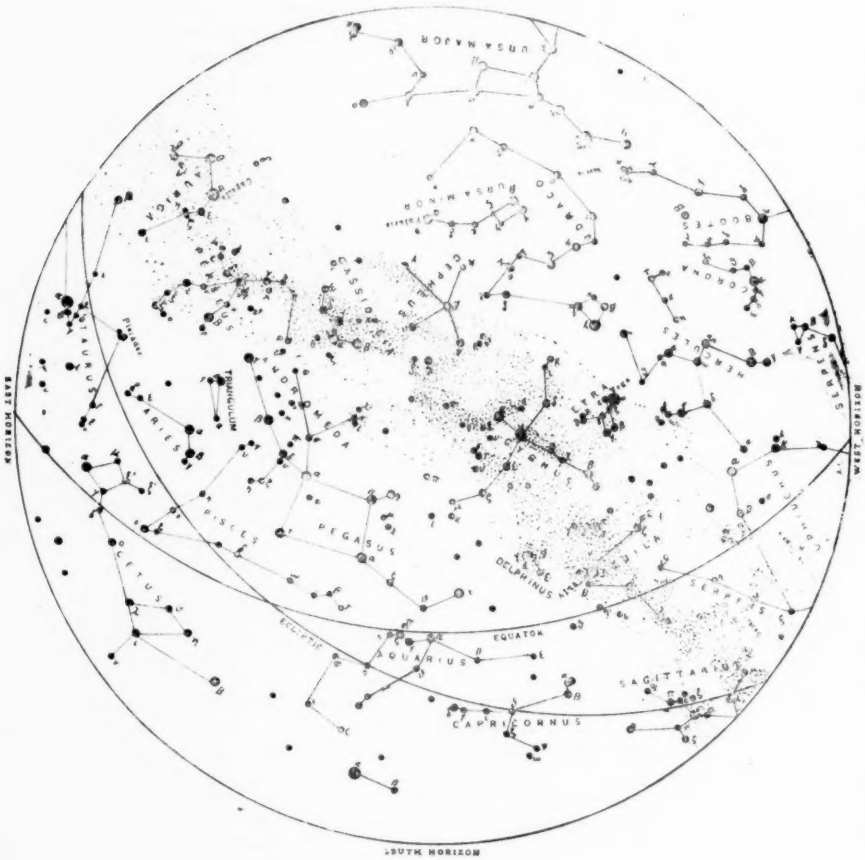
Between the point overhead, and the eastern horizon, are the constellations of Aries, the Triangles and Andromeda. Between Andromeda and Cepheus, we find Cassiopeia, or rather Cassiopeia's Chair. (The stars Beta, Alpha and Gamma mark the chair's outline). Perseus, the Rescuer, is in the northeast, between Cassiopeia, and Taurus which is rising between the northeast and eastern horizon. The Pleiades, and Aldebaran, (the glaring eye of the Bull), have already made their appearance. Directly northeast we find the Charioteer (*Auriga*), with the bright Capella, and between the Charioteer and the Great Bear, is the inconspicuous constellation of the Camelopard (*Cameloperdalis*).

The constellations are to be found in the above positions on September 29th,

at half past nine, on October 7th at nine o'clock, on October 15th at half past eight o'clock, and on October 22nd at eight o'clock.*

CONSTELLATION OF AQUARIUS.

This constellation is represented by the figure of a man, pouring out water from an urn. Its mean declination is 14° S. and its mean right ascension 335°,



THE CONSTELLATIONS AT 9 P. M., OCTOBER 1, 1897.

or $22^h\ 20^m$; it being 1 hour and 40 minutes West of the equinoctial colure; its centre, is, therefore, on the meridian the 15th of October.

* *Half Hours with the Stars.* Map X. By R. A. Proctor. A new edition of this star Atlas has just been published by Longmans & Co., New York.

It contains 343 stars, of which the four largest are of the 3rd magnitude, viz: *Alpha*, *Beta*, *Zeta*, and *Delta*.

According to Grecian mythology, this constellation is the famous Gangmeda, a beautiful youth of Phrygia, son of Tros, king of Troy. He was taken up to heaven by Jupiter as he was tendfng his father's flocks on Mount Ida, and became the cup-bearer of the gods in place of Hebe.

SEEN WITH AN OPERA-GLASS.

Just above *Mu* and *Epsilon*, "you will find an attractive arrangement of small stars in its neighborhood. The star Delta indicates the place where, in 1756, Tobias Mayer narrowly escaped making a discovery that would have anticipated that, which a quarter of a century later made the name of Sir William Herschel well-renowned. The planet Uranus passed near Delta in 1756, and Tobias Mayer saw it, but it moved so slowly that he took it for a fixed star, never suspecting that his eyes had rested upon a member of the solar system, whose existence was, up to that time, unknown to the inhabitants of Adam's planet."

"The star *Tau* is double and presents a beautiful contrast of color, one star being white and the other reddish-orange—two solar systems, it may be, apparently neighbors as seen from the Earth in one of which the daylight is white and in the other red!"*

ANNULAR NEBULA IN AQUARIUS.

But the chief object of interest in Aquarius is undoubtedly the Annular Nebula, a confirmation, as it were, of the great nebular hypothesis. In Lord Rosse's great telescope it presented the appearance of a round ball with a ring around it, resembling the planet Saturn, and on each side are two masses, presumably planets already formed, and part of a gigantic solar system.

THE CONSTELLATION CEPHEUS.

Cepheus is represented on the old maps as a king, the head and upper part of his body being immersed in the stream of stars composing the Milky Way, whilst he stands in a commanding attitude, his left foot over the pole, and his sceptre extended towards Cassiopeia.

TELESCOPIC OBJECTS OF INTEREST.

Alpha Cephei (Alderamin), is a double star. It is of the third magnitude and white, while the companion star is of the tenth magnitude and pale blue. R. A. $21^h\ 15^m\ 56^s$; Decl., $+\ 62°\ 7'.1$.

Beta Cephei, is a double star of the third magnitude, and white. The companion star is of the eighth magnitude, blue, and 14″ distant. Its mean R. A. is $21^h\ 27^m$; Decl., $+\ 70°\ 4'.6$.

CONSTELLATION OF PEGASUS, THE WINGED HORSE.

This constellation occupies a large space in the heavens between the Swan, the Dolphin and the Eagle, on the west, and the Northern Fish and Andromeda on the east. It is easily distinguished from other constellations, on account of four large stars, about 15° apart, forming the figure of a square, called the *square of Pegasus*. According to Grecian fable, this is the celebrated horse, the favorite of the Muses, and given to Bellerophon, to aid him in conquering the Chimæra, a monster with three heads. After the destruction of the monster, Bellerophon attempted to fly up to heaven upon Pegasus, but Jupiter was so displeased at his

* Astronomy with an Opera-Glass. pp 68-69.

presumption, that he sent an insect to sting the horse, which threw its rider. Bellerophon fell to earth, and Pegasus continued its flight up to heaven, and was placed by Jupiter among the constellations.

TELESCOPIC OBJECTS OF INTEREST.

15 M. (H, 4670) R. A., $21^h\ 24^m\ 34^s$; Dec., $+\ 11°\ 40'.3$. "A splendid globular cluster, nebulous in small telescope, but resolvable with a comparatively moderate aperture. There are some stars in the field, but Smyth remarks that the globular mass strikes the senses as being almost infinitely beyond these apparent comites."*

PISCIS AUSTRALIS, THE SOUTHERN FISH.

This constellation is directly south of Aquarius, and is represented as a fish drinking the water which Aquarius pours from an urn. This constellation is supposed to have originated from the transformation of Venus into the shape of a fish, when she fled at the approach of the monster Typhon. The constellation contains 97 stars, one of the first magnitude, two of the third, and five of the fourth.

Alpha (*Fomalhaut*) is the leading brilliant of this constellation. It is a fine ruddy star, with a very distant dusky blue companion of the ninth magnitude.

THE CONSTELLATION OF ARIES, THE RAM.

Aries is one of the Zodiacal signs. It contains 148 stars, of which one is of the second, one of the third and two of the fourth magnitudes. According to mythologists, this is the ram which bore the golden fleece, and carried Phryxus and his sister Helle through the air, when they fled to Colchis from the persecution of their mother Ino.

Arietis is one of the nine conspicuous stars lying along the Moon's path, that are used by nautical men for determining their longitude at sea, thence called *nautical stars.*

TELESCOPIC OBJECTS OF INTEREST.

Gamma Arietis, R. A. $1^h\ 47^m$, Dec., $+\ 18°\ 42'$. *Gamma* is a beautiful donble star, "the components being of the 4 2 magnitude, and 4.4 magnitude, observed by Hook, in 1644, and described by him as remarkable in the highest degree."†

Epsilon Arietis is a double star of the fourth and sixth magnitudes, distance 1.5″. Probably both the stars are variable, as conjectured by Struve.‡

Beta Arieties, R. A. $1^h\ 48^m\ 33^s$, Dec., $+\ 20°\ 16.2'$. "A pretty double, but will prove decidedly difficult in a small telescope. The larger star is of the third magnitude, and grey; whilst the smaller one is of the eleventh magnitude and dusky."§

PLANET NOTES FOR OCTOBER.

H. C. WILSON.

Mercury, *Venus* and *Jupiter* are morning planets together, all seen toward the east about an hour before sunrise. Venus will catch the eye of the observer first, shining with a brilliancy much greater than that of the surrounding stars

* Amateur Telescopist's Handbook. p. 147. F. M. Gibson.
† Klein's Star Atlas, p. 15.
‡ Ibid. p. 18.
§ The Amateur Telescopist's Handbook. p. 100. Gibson.

of Leo. Directly toward the east of Venus will be found Jupiter, brighter than the stars but feeble when compared with the transcendent glow of his neighbor. Mercury is quite near to Jupiter, shining with the brightness of a first magnitude star, but with its lustre dimmed by the strong twilight. Mercury will be at greatest elongation, 18° west from the Sun, Oct. 7.

The relative motions of the three bright planets will form an interesting study to those who are willing to get up early in the morning to view them. Jupiter and Venus are moving eastward among the stars. Mercury during the last days of September has been moving westward; passed Jupiter Sept. 27; became stationary Sept. 30; and has now turned eastward. It will pass Jupiter again on the morning of October 6. This will be a good time to identify Mercury because of its proximity to Jupiter; conjunction occurs at 2^h A. M., Central Standard Time. Mercury will then be only 12′ north of Jupiter, in the same field of view in the telescope. Venus, being at the beginning of the month about 12° west of Jupiter, will by virtue of her more rapid movement overtake the latter on the 19th, and by the end of the month will be nearly an equal distance to the east of the giant planet. Their conjunction occurs at 3 P. M. Oct. 19, when Venus will be 28′, or a little less than the Moon's diameter, north of Jupiter. The astrologers and weather prophets will doubtless make much of these conjunctions of mighty worlds But when we reflect that these worlds are 81,000,000, 132,000,000, and 587 000,000 miles, respectively, from us, at the moment when they happen to come nearly into line with each other, we may presume that our earth will pursue its way slightly, if at all, disturbed by any other forces than that of gravitation emanating from these bodies.

Mars is out of view behind the Sun.

Saturn and *Uranus* are too near conjunction with the Sun to be visible.

Neptune is in good position for observation from midnight until morning. The position of the planet Oct. 1, is Right Ascension $5^h\ 27^m\ 50^s$; Declination north 21° 52′. The motion during the month is very slow westward, the right ascension decreasing $1^m\ 36^s$ and the declination decreasing 2′. The planet will thus be found among the telescopic stars from a degree to a degree and a half northwest of the third magnitude star δ Tauri.

Sunspots have been unusually abundant during September. On the 4th three large groups were noted, numbering in all 72 separate umbræ. The surface of the Sun bore evidence of violent disturbance. This disturbance had largely subsided on the 13th, but there have been no days on which spots have not been visible.

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U CEPHEI.

1897.

	d	h
Nov.	5	16
	10	16
	15	15
	20	15
	25	15
	30	14

ALGOL.

1897.

	d	h
Nov.	3	23
	6	19
	9	16
	12	13
	15	10
	18	7

ALGOL CONT.

1897.

	d	h
Nov.	26	21
	29	18

S CANCRI.

Nov.	2	15
	21	14

RS SAGITTARII.

1897.

	d	h
Nov.	6	14
	23	11
	28	7

U CORONÆ.

Nov.	12	14
	19	12

λ TAURI. 1897		S VELORUM. 1897		W DELPHINI. 1897	
	d h		d h		d h
Nov.	4 9	Nov.	8 22	Nov.	3 16
	8 8		14 21		8 11
	12 7		20 19		13 7
	16 5		26 18		

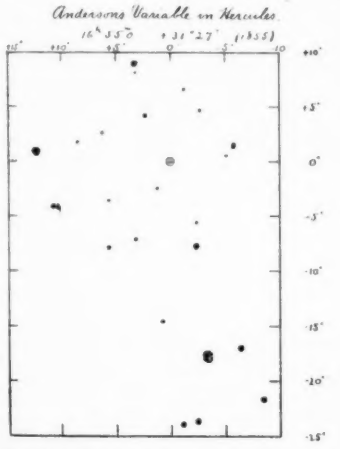
Maxima and Minima of Long Period Variables.

1897 December.

MAXIMA.		Day	MAXIMA Cont.		Day	MAXIMA Cont.		Day
419	U Andromedæ	25:	5194	V Bootis	24	8591	V Cephei	27
466	U Piscium	27	5438	Y Libræ	18	8600	R Cassiopeæ	30
513	R Piscium	19	5511	RS Libræ	25		MINIMA.	
1222	R Persei	3	6512	T Herculis	25			
1577	R Tauri	3	6794	R Lyræ	12	1582	S Tauri	20:
2539	R Canis min.	13	7045	R Cygni	1	4492	Y Virginis	6:
2676	U Monocerotis	6	7077	T Pavonis	28	4557	S Ursæ Maj.	11
2815	U Geminorum	13:	7242	S Aquilæ	30	4596	U Virginis	23
2946	R Cancri	8	7260	Z Aquilæ	28:	4826	R Hydræ	6
3170	S Hydræ	6	7431	S Delphini	17	5237	R Bootis	1
3637	S Carinæ	31	7560	R Vulpeculæ	29	5887	V Ophiuchi	8:
3825	R Ursæ Maj.	8	7609	T Cephei	1	6449	T Draconis	20:
4225	X Centauri	31	7783	RU Cygni	7	6921	S Sagittarii	31
4896	T Centauri	7	8068	S Lacertæ	1	7404	R Microscopii	20
5157	S Bootis	7	8373	S Pegasi	17			

The above ephemeris was computed for POPULAR ASTRONOMY directly from the elements given in Chandler's Third Catalogue and supplements. A colon after the date signifies doubt.

Another New Variable Discovered by Anderson. In *Astronomische Nachrichten*, No. 3440, Anderson has the following note. "A star not mentioned in the BD. whose place for 1855.0 is R. A. 16^h 55.0^m, Decl. $+ 31° 26'$ should be inserted in the list of Variables. I cannot now tell at what time I first saw this star; this only I can say that I had noted it as being a faint star of the ninth magnitude and of about the same brightness as BD. $+ 31°$, 2949. Several times in the autumn of 1896 I looked in vain for it with my 2¼ inch refractor, although I could always see a 9.6 magnitude star not given in the BD. whose coordinates for 1855 are approximately 16^h 55.2^m and $+ 31° 34'$, (*d* in the accompanying list). However on examining the heavens on the 22nd and 26th of this month (July, 1897) I found that the missing object had reappeared, and that it was much brighter than the 9.6 magnitude star mentioned above. On both occasions it was of the same brightness as BD. $+ 31°$,2949, whose magnitude seems to be



correctly estimated in the BD. as 9.2. I do not think that the place given above can be wrong to the extent of more than 1′; but mistakes may be avoided if those who look for this variable remember that it lies farther from + 31°,2951 (*e*) than from 2949 (*b*), and also that + 31°, 2945 (*h*), 2946 (*k*), 2949 (*b*) and the variable and the 9.6 magnitude comparison star (*d*) are nearly in a straight line."

On receiving the above I immediately looked for the star and have made the following estimates, using Anderson's magnitudes for the comparison stars:

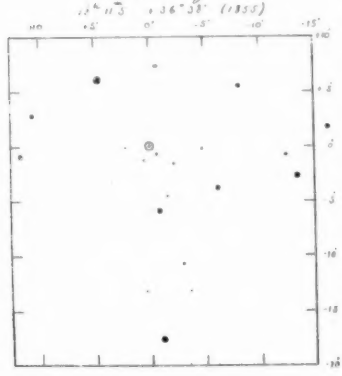
	Mag.		Mag.
1897 Aug. 23	9.5	Aug. 29	9.8
24	9.5	30	9.8
27	9 7	Sept. 3	10.0

For the sake of clearness I have omitted the lettering on the accompanying chart. The comparison stars can be readily located by means of the coordinates in the following list. The magnitudes given are approximate but will aid inidentifying the stars.

	Co-or. from V.				Co-or. from V.		
	R. A.	Dec.	Mag.		R. A.	Dec.	Mag.
h	− 8.6	− 21.8	9	*i*	+ 0 6	− 14.7	11
k	− 6.5	− 17.1	9	*s*	+ 1.1	− 2 5	12 3
f	− 5.9	+ 1.5	10.1	*o*	+ 2.2	+ 4.1	11.0
r	− 5.1	+ 0.6	11.7	*w*	+ 3.1	− 7.1	11.5
a	− 3.5	− 17.8	4.0	*l*	+ 3.1	+ 8.0	12.8
n	− 2 8	+ 4.7	12.1	*d*	+ 3.2	+ 8.9	9.6
y	− 2 5	− 23.9	9.5	*x*	+ 5.7	− 7.9	11 5
b	− 2 4	− 7.8	9.2	*t*	+ 5 7	− 3.5	12.3
u	− 2.4	− 5.5	11.9	*p*	+ 6.2	+ 2.6	11.5
m	− 1.3	+ 6.6	12.1	*q*	+ 8.5	+ 1.8	11.7
z	− 1.1	− 24.0	10	*e*	+ 12.1	+ 0.8	8

The star *y* is BD. + 31°,2948, and its position and magnitude are given by Argelander in Vol. VI of the Bonn publications. The star *a* is *ε* Herculis, which makes the identification of the field very easy.

6549 W LYRAE. R. A. 18^h 11^m.5, Dec. + 36°38′, (1855). This is a comparatively new variable and is given here on account of its rapid change and its convenient position. It is D.M. + 36°,3066 and was variously estimated as 8.5 to 9.3 magnitude by the D. M. observers. It was invisible to Anderson in December 1895 but he found it 9.2 magnitude 1896 Jan 8. Hartwig found a maximum near the end of January 1896 and Yendell another Sept. 13, at 8.2 magnitude. I found a minimum 1896 Dec. 25, 12.6 mag. and another 1897 July 19, 12.5 mag. giving a period of 206 days. The field is easily found, being 1° north preceding *kappa* Lyrae. As in the previous case I omit the lettering on the chart, and give the coördinates in the list in minutes of arc both in R. A. and Dec.



COMPARISON STARS FOR 6549 W LYRAE.

	Co-or. from V. R. A.	Dec.	Mag.		Co-or. from V. R. A.	Dec.	Mag.
	′	′			′	′	
p	−16.2	+ 1.7	9.4	*n*	− 1.1	−17.5	8.1
e	−13.5	− 2.8	8.8	*g*	− 1.0	− 6.0	10.0
s	−12.4	− 0.9	10.7	*l*	− 0.7	− 0.7	12.4
d	− 8 1	+ 5.5	10.8	*t*	+ 0.3	−13.2	12
f	− 6 1	− 3.8	10.0	*x*	+ 0.5	− 1.3	12.6
m	− 4.9	− 0.2	12.3	w	+ 2.1	− 0.1	12.7
u	− 3.6	−13 2	12	*a*	+ 4.6	+ 6.0	8.6
p′	− 3.0	−10.7	12.2	*b*	+10 7	+ 2.9	11.2
k	− 2.1	− 1.6	12 3	*c*	+11.7	− 0 9	10.1
h	− 1 6	− 4 5	12.5				

If observations begin early in October they will probably be in time to determine the next maximum.

7792 SS CYGNI. The maximum reported in the September number has received a very gratifying confirmation from the observations of Mr. Zaccheus Daniel, of Hawthorn, Pa., who observed it with a 4 inch telescope. Mr. Daniel's series is unique, in that he secured an observation every night from Aug. 6 to 21, inclusive, thus covering the whole time during which the star was above normal light. For convenience of comparison with the data in the September number I have reduced his observations with my light scale, which differs slightly from his.

GREENWICH MEAN TIME.

1897, Aug.	Mag.	1897, Aug.	Mag.
6.58	11.4	14.58	9.3
7 63	11.2	15.63	9 6
8.67	9.0	16.58	9.9
9.58	8 5	17.58	10.1
10.58	8.8	18 63	10.9
11 63	8 8	19.58	11.3
12.67	8 9	20.67	11 3
13.67	9.1	21.63	11.4

The date of maximum from the above observations depends somewhat on the weight given to the comparison of Aug. 9, which Mr. Daniel notes as "hurriedly made, through rift in clouds." A consideration of the plotted points would indicate that the weight should not be more than 1/4 or 1/5, and by so doing the other points fall very close to a smooth curve, giving the maximum Aug. 10.5 at 8.8 magnitude. The date is thus a complete confirmation of Mr. Sperra's and my own, and the difference of magnitude is no greater than might be expected from the difference in eyes, aperture and step values. It is to be hoped that Mr. Daniel will continue his valuable observations.

Marengo, Ill., 1897 Sept. 8.

GENERAL NOTES.

The Nebula of Orion.—In Vol. I., Part 7, of the "Publications of the Leander McCormick Observatory of the University of Virginia," is an account of eye observations of this nebula made by the director, which it should be interesting to compare with the investigation by Dr. Scheiner, in Vol. XI. of the "Publicationen des Astro-physikalischen Observatoriums zu Potsdam," of the details of the same nebula as recorded on several photographs. Dr. Scheiner has particularly considered the question of connection between the nebula and the neighboring stars, and concludes that undoubtedly such relationship does exist.

Naming and Numbering of Small Planets.—The asteroid (354) 1893 *A*, discovered by Charlois Jan. 17, 1893, has been named *Eleonora* by its discoverer. Also (416) 1896 *CS*, discovered by Charlois May 4, 1896, has received the name *Vaticana*. The planet 1896 *DC*, discovered by Charlois Dec. 28, 1896, has received the number (425) but has not yet been named.

Interplanetary Communication.—The September number of the "*Bulletin de la societe astronomique de France*" contains a ten page article on "Means of communications with the planets," which was written by Charles Cros in 1869. The article is quite interesting, although the ideas of the author are of course fanciful, entirely impracticable, but perhaps we should not say impossible. The method of communication suggested is by series of flashes of electric light from powerful reflectors, and the author attempts to show mathematically that it would not be impossible to produce a light sufficiently intense to be visible at the distance of the nearer planets. Camille Flammarion adds a note that M. Cros was the first inventor of the phonograph and of photography in colors.

New Short Period Binary β 395.—A telegram in the *Astronomical Journal* No. 412 from Dr. See to Mr. Lowell announces that the binary star β 395 = 82 Ceti revolves in 16 years; the companion is near periastron, angle 278°, distance 0″.22. This object has heretofore not been suspected to be rapid, but it appears from Dr. See's investigations that one and a half revolutions have been completed since Burnham's discovery in 1875, and we thus have one of the most interesting stars in the heavens. At present the motion is very rapid and the star should be measured by observers with powerful telescopes. The position is

$$\left.\begin{array}{lllll} \alpha = & 0^h & 32^m & 9^s.9 \\ \delta = 25^\circ & 18' & 37''.3 \end{array}\right\} 1900.0$$

Total Eclipse of the Sun.—What is the degree of darkness on such an occasion? How many of the readers of this journal have ever seen a total eclipse of the Sun?—Doubtless the most magnificent spectacle the human eye has ever beheld. One who has not seen for himself, knows and can know nothing about it, by mere words of description. And all who have enjoyed that sight, will substantiate what I say.

In this latitude the shadow usually travels about 1,700 or 1,800 miles an hour. There is no sharp line separating the umbra and the penumbra.

At the time of the total eclipse of the Sun, Aug. 7, 1869, I was on the summit of a hill more than 300 feet high, and had an unobstructed view to the west in the direction of the Sun—and none of our large party saw the approach of the dark shadow, although some tried. After totality came, I examined the sky for stars, and I saw five, as I now remember, but how many of these were planets I cannot now tell, having no almanac of that year by me. But it is safe to say that not more than three or four of the brightest stars of the first magnitude are seen on such an occasion. One can easily read ordinary print by the light remaining.

I have sometimes seen it stated that "the shadow of the Moon" creeps over the Sun, etc. Was there ever in all the multitude of absurd things, one more absurd than this? The Moon casts a shadow on the disk of the Sun.

R. W. McFarland.

Observatory of Vassar College.—A large part of the time of the department of Astronomy is devoted to instruction, hence the work done must be of a character which does not suffer because of frequent interruptions. The independent work carried on has been of two kinds. Observations of comets and asteroids have been made, the results of which have been published in the Astronomical Journal from time to time. This kind of observation is particularly adapted to the size of the glass and the uncertain steadiness of the air at Poughkeepsie. A new filar micrometer just arrived from Warner & Swasey's workshops, will add greatly to the equipment of the Observatory.

A year ago, through the generosity of Miss Catherine Bruce and Mr. F. F. Thompson, one of the Vassar trustees, the Observatory was able to secure from Repsold a machine for measuring photographic plates. The work in connection with the machine has been carried on under the advice of Professor Jacoby, of Columbia University, through whose agency the plates were secured. The plates now being studied were taken at the Helsingfors Observatory by Professor Donner. It is hoped that this kind of investigation which is independent of weather can be quite extensively developed.

Occasional observations of variable stars have been made. The Observatory has also added to its collection of planetary drawings. The series on Jupiter was begun in 1892. F.

United States Naval Observatory.—When writing a brief note in the July number of this publication about the United States Naval Observatory, we did not suppose that anybody would be much interested in it, much less did we think that it would receive more than a passing notice of any of the officials of that Institution. In this view of the matter we were evidently wrong, for in the admirable article by Professor Harkness, astronomical director of the Naval Observatory, which was called out by it, this paragraph occurs: (See pages 223 and 224.) "We have all been intensely interested in the spicy article on page 166 of the July number of POPULAR ASTRONOMY, wherein you so graphically comment on a report that the peace and quiet at the Naval Observatory has been a little disturbed during recent months; alas, alas, the more we have read the article the more mysterious it all becomes. There is not a man here who has ever heard of any such disturbance of the peace, and we are all hoping that you will lay us under yet greater obligations by stating clearly in the next number of your able journal who is quarreling and what they are quarreling about."

Is it not a little singular that "*we have all been intensely interested*" (italics mine) in a report that "the quiet of the Naval Observatory has been a little disturbed during recent months?" Then again, "the more we have read the article the more mysterious it all became." What a dilemma! Have we said anything about quarreling? We would not have used such a term in regard to high government officials. They never quarrel; they simply differ in opinion. That is all. "There is not a man here who has heard of any such disturbance of the peace." That is, "quarreling" is meant. This information is interesting and it may be of use to us, though we had not anticipated it for present or future need.

It may here be properly added that differences of opinion do exist as to the management of the Naval Observatory and in relation to the work done there, by astronomers both inside and outside of the Observatory Staff. Whether these differences of opinion held by members of the Staff are sufficient to hinder or prevent the best astronomical work is the real question. Evidently, Professor Harkness thinks not, as we infer from the tenor of the communication referred to. In

this view some others related closely to the Staff, at least partially concur. From this view many astronomers outside dissent. We think it is not too much to say that the Naval Observatory is not doing the work which the astronomers of the country and of the world have a right to expect, in view of its very liberal support. We also believe we are justified in saying, that there is a difference of opinion at the Observatory, as to whether good work will ever be done as long as the present system of administration is continued. We are sorry to say this just now, because Professor Harkness, the astronomical director, has been and is esteemed a personal friend, and the course he has pursued for the last twelve years or more in regard to the Naval Observatory has been consistent with his views of right, however much others may have differed from him.

We believe it is easy to see how work that ought to be done is hindered, if this state of things exists. At least the impression is out that something is wrong at the Naval Observatory and that a spirit of discouragement pervades the Staff. Are we wrong in this view? In the matter of routine observations we have seen no published volume since that for the year 1890. No report has been received since that for 1893. Possibly these and other later ones may have been sent and failed to reach us but we think not.

Shall we repeat very courteously, what's the matter at the Naval Observatory?

A Paradise for an Astronomer.—We receive in newspapers the daily record of the weather in widely separated parts of the country, giving also a monthly summary of the condition of the sky during the several months of the year. The condition of the sky at night however is never mentioned. As night is the astronomer's accepted time it may be interesting to compare notes as to the No. of clear nights each Observatory has had, but as far as I know we seldom if ever get the sum total. The following giving the No. of clear nights during the last five months may open the eyes of astronomers as to this remarkable climate for astronomical work. One of the singular things about it is, there are more clear nights than days, which is the reverse of the conditions which existed at the Warner Observatory at Rochester, N. Y. I commence the record with my return to the Observatory April 3.

No. of clear nights in					April	24
"	"	"	"	"	May	25
"	"	"	"	"	June	28
"	"	"	"	"	July	31
"	"	"	"	"	Aug.	30

Of course the No. will be less during the rainy season, but they are numerous then. What Observatory can boast of but 3 cloudy nights in three months?

Lowe Observatory, Echo Mountain, Cal. LEWIS SWIFT.
Sept. 12, '97.

Loss of Dr. See's Library by Fire.—The readers of POPULAR ASTRONOMY and men of science generally will hear with extreme regret that the fire which destroyed the Grand Canyon Hotel at Flagstaff, Arizona, Sept. 14th, consumed also the larger part of Dr. See's valuable scientific library. The fire was discovered about 2 A. M. and had already made such headway that the fire department was wholly unable to combat it. In the darkness and confusion attending the evacuation of the burning building all that could be done was to save the records of the Lowell Observatory, the general manuscript catalogue of all double stars within 75° of the south pole, and a few works such as the

Mecanique Celeste—all else, the correspondence, pictures, personal effects, and the library of books being a total loss.

We understand that Dr. See has already begun rebuilding his library, and as he has himself contributed extensively to the libraries of other astronomers, we need not suggest the propriety of exchanges of such work as will be useful at this time. As one of the main purposes of scientific works is their utility for the progress of knowledge, it would seem that it is just such a workshop as Dr. See's library that men of science would desire to deposit copies of their surplus papers. At the best, however, years will be required to replace what the fire has consumed, and unfortunately many important letters and precious documents can never be restored.

Sensational Astronomy.—We have seen in the Philadelphia "Press," the New York "Journal," the Chicago papers and other dailies west not a few, most sensational accounts of what appeared in POPULAR ASTRONOMY in an article written by S. Corrigan, of St. Paul. In these wildly sensational articles and illustrations Mr. Corrigan was mentioned as director of Goodsell Observatory and on this account not a little cheap punning was attempted in regard to the Observatory and its honored name. We believe that most, if not all, of our readers know that Mr. Corrigan is not connected with Goodsell Observatory nor has he ever been, as much of an honor as it would have been, if such relations had existed. Mr. Corrigan has been occasionally a voluntary contributor to POPULAR ASTRONOMY, and it is a pleasure to say that he is a scholar in mathematics and astronomy widely and favorably known in this country and abroad. Some astronomers do not support Mr. Corrigan's views, in all respects, especially in regard to some of the deductions which he has recently published. But we think this is no good reason why he should not be given a respectful hearing and have the privilege of recording his views in current publications, especially when he assumes all responsibility in regard to scientific matter so presented.

But when a reporter wants something sensational it is easy enough to find it in unguarded statements of any writer. In this instance, we certainly know that no one could be more surprised than Mr. Corrigan is at the unfair and the garbled use that has been made of his meaning in the article above referred to. Who is not at the mercy of such news-mongers so far as the uninformed are concerned? Usually such matters are not worthy of attention at all, and we would not have noticed this one, but for the fact that some of our friends in the East are hurt by these shameful notices and have written us freely about them. To all such we want to say, do not mind any such thin effervescence! It is only a little news-*paper astronomy*. Not one single life is yet in any serious danger.

Professor Young's Supplemental Notes to Edition of The Sun for 1895.—We have elsewhere printed an article on the Adjustment of the Spectroscope, which is one of a series of notes recently prepared by Professor C. A. Young to be appended to the next impress of the revised edition of his book entitled *The Sun*. Other important notes follow. We are favored by the author and the publishers, Messrs. D. Appleton and Company, New York City, in having the permission to print these notes in advance of their publication in connection with the edition for which they are prepared.

The Spectra of Some Elements.—This note is supplemental to page 81 of *The Sun* above referred to.

As a rule, the spectrum of a luminous gas consists of a great number of lines, sometimes, as in the case of iron vapor, to be counted by thousands.

In the spectra of many of the elements there is no obvious regularity in the arrangement and spacing of the lines; but in many also the lines, as has been shown by Balmer, Kayser, and Runge, and other observers, fall more or less completely into "series," in which they are spaced with perfect regularity according to very simple mathematical formulæ.

The lines of hydrogen, for instance, form a single series; beginning with the C-line in the red, we have next F in the blue, and that is followed by some twenty more (already observed in the laboratory and in the spectra of the Sun and various stars) which crowd more and more closely together as they run up into the ultra-violet region of the spectrum, their wave lengths being all given by one simple formula, $\lambda = 3646.1 \left(\frac{n^2}{n^2 - 16.}\right)$ in which λ is the wave length of a line on Rowland's scale, and n is always one of the *even* numbers, 6, 8, 10, 12, etc., beginning with 6, since 4 or any smaller number would give an impossible result.

It is a very curious fact that, while ordinarily we find in the spectrum of hydrogen only lines that correspond to the even values of n, Pickering has found in the spectra of certain stars, of which Zeta Puppis is the most conspicuous example, a series of intermediate lines which fall in between the lines of the usual hydrogen series and correspond accurately to the same formula with the *odd* values of n (5, 7, 9, 11, etc.,) replacing the even.

More frequently than otherwise the spectrum of a substance contains more than one series—that of helium, for instance consists of *six*. In some cases the series run in the opposite direction, the successive lines crowding more and more closely together as they approach the *red* end of the spectrum; this is the case with the hydrocarbon bands which characterize the spectrum of a comet.

Very often, perhaps usually, the spectrum of an element contains besides the lines which fall into series a number of others which seem to follow no law; and not unfrequently these unsocial lines are among the most important and conspicuous of all: for instance, the H and K lines of calcium.

The explanation of these peculiarities of spectrum structure is not yet known, but must be connected with the structure of the molecule itself.

On the Reversing Stratum and its Spectrum, and on the Spectrum of the Corona.—This note is supplemental to pages 83, 325 and 339, and to pages 258-262.

The observation made by the writer in 1870, described on pages 82 and 83, received a beautiful photographic confirmation during the total eclipse of 1896. Mr. Shackleton, the photographer of an English party at a station in Nova Zembla (the only party which was not baffled by bad weather), secured an instantaneous photograph at the critical moment with a so-called "prismatic camera," which is simply a camera with (in this case) two large prisms in front of its lens, no collimator being used—a photographic "slitless spectroscope."

When the Sun's disk is reduced to an extremely narrow crescent by the encroaching Moon, this crescent itself acts like the slit of an ordinary spectroscope, and photographs taken with such an instrument immediately before totality are just like the usual solar spectrum, except that the dark Fraunhofer lines are replaced by dark crescents—*negative* images, so to speak, of the still uncovered portion of the disk. As soon, however, as the photosphere disappears, the remaining, much fainter, crescent is simply the solar atmosphere, and if the observation

of 1870 was correct, its photograph ought to show a series of *bright* images replacing the former dark ones, and it did.

Mr. Shackleton watched the waning crescent with a small direct-vision prism held in the hand, and at the instant when the brilliant dark-lined spectrum vanished he "pressed the button" and caught on his plate the "flash spectrum," as it has been called by Mr. Lockyer. The exposure was about half a second. The photograph shows a long range of several hundred bright, curved images, of which there are nearly 250 in the blue portion of the spectrum between *F* and *H*. About 25 are much more extensive and conspicuous than the others, and are images of the chromosphere and prominences. They are due to hydrogen, calcium, helium, strontium, and one or two other elements which often appear in the chromosphere. The rest are simply reversals of the Fraunhofer lines, as Mr. Shackleton has shown by developing the flash-spectrum into a bright-line spectrum of the usual form (which is easily done by a simple mechanical contrivance), and comparing it with an ordinary dark-line solar spectrum photographed with the same camera and prisms, but with the addition of a collimator and slit. The agreement is practically complete, although there are two or three somewhat conspicuous Fraunhofer lines which are missing in the flash-spectrum, probably because they originate not above the surface of the photosphere, but in its depths, as probably also do the wide hazy shadings that accompany the *H* and *K* lines and some others, but this is a matter for further investigation.

A second photograph, taken not more than five or six seconds later, shows only the chromospheric images, proving of course that the stratum of the solar atmosphere which produces the Fraunhofer lines by its absorption must be extremely thin. This is perfectly in accordance with the view expressed on pages 325 and 339, and does not at all favor the opposite "Dissociation Theory" of Mr. Lockyer, according to which the lines, many of them at least, are produced only at a considerable elevation, where the temperature is low enough to allow the recombination of elements dissociated in the hotter regions underneath.

A photograph made by the same instrument about the middle of the eclipse, with an exposure of nearly a minute, shows very finely the green coronal ring, corresponding to the old "1,474 line" and several others in addition. These are all in the violet part of the spectrum, and are extremely faint, excepting one which is a little below *H*. They are all probably due to the same hypothetical element, still unidentified, but provisionally named "coronium." The photograph also seems to make it certain that *hydrogen*, *helium*, and *calcium*, though brilliantly conspicuous upon the plate in the images of the prominences, *are entirely absent from the corona*, a result agreeing with that deduced from similar photographs made in 1893, but only recently published. It is quite clear that the earlier observations (referred to pages 260, 261 and 262) were misleading from the fact that the apparatus did not sufficiently guard against the effects of the illumination of the air by light from the prominences.

Shift of Spectrum Lines Caused by Change of Pressure.—This note is supplemental to page 98.

An important series of observations, made at the Johns Hopkins University by Humphreys and Mohler in 1895-'96, has shown conclusively that changes of pressure alter the position of lines in the spectrum in precisely the same way as does motion in the line of sight (approach or recession).

Increase of pressure upon gaseous molecules which are emitting or absorbing light *shifts the lines of the spectrum toward the red* by an amount which is pro-

portional to the change of pressure and to the wave-length of the line affected, but is different for different elements, and, in some cases at least, differs for the lines belonging to the different "series" (Note B, page 355) in the spectrum of a given element; thus, for instance, the shift of *H* and *K* is only half as great as that of the calcium-lines which belong to the two regular series.

This pressure effect is very slight; in case of most substances a pressure change of ten atmospheres (150 pounds to the square inch) produces a displacement much less than would a velocity of a mile a second. Still, even this amount is a quantity which can not be neglected in the investigation of the motions of the stars, and the comparison of the difference of the shift of lines of different elements may ultimately give us important information as to the atmospheric pressures existing upon the stellar surfaces, and so of the intensity of gravity there prevailing. In the "reversing layer" of the Sun the pressure appears to be between four and seven atmospheres.

Equatorial Acceleration of the Sun.—This note is supplemental to pages 141 to 144.

Recent important and elaborate mathematical investigations by Wilsing, of Potsdam, and Sampson, of Durham College, England, point to the conclusion that the explanation of the "Equatorial Acceleration" of the Sun which has so long perplexed the students of solar physics, is to be sought not in forces and conditions at present acting, but in a slowly dying "survival" from an earlier state of things. As Wilsing expresses it, "We are relieved from the difficulty of accounting for the maintenance of these currents on mechanical and physical principles, since they appear as the result of earlier conditions of motion." While the present conditions are such as tend to destroy the observed inequalities of motion, and will ultimately bring the Sun to the same state of uniform rotation as a solid globe, yet the process is so slow that the present behavior will continue practically unchanged for thousands, if not for millions, of years. Near the center of the Sun this state of uniform rotation has probably been already reached, but it will be ages before the surface drifts will disappear, and the change in a century or two will be quite too small to be detected by any possible observations.

It is perhaps worth while to add in this connection that the spectroscopic observations of Jewell and others at Johns Hopkins give results as to the Sun's rotation in practical agreement with those of Dunér, quoted on page 101. They appear also to indicate further that the lower lying strata of the solar atmosphere move more slowly than those at a higher elevation, and take longer to complete a rotation. But the observations are so delicate that this can not yet be considered as established beyond question."

Lick Observatory Trouble.—The *Examiner* and *Chronicle*, San Francisco, California, under date of Sept. 22 contain full accounts of more "unpleasantness" between members of the Staff and Director Holden. It seems, that some time ago, Professor Colton made charges against Professor Holden, and that, for some reason, the document containing the charges did not come before the Board of Regents of the University until quite recently and then in an irregular way, so much so, that responsible persons felt themselves much aggrieved at the unfairness with which they were treated in the mean time. As a consequence, if we can rely on the California papers of Sept. 22, the Board of Regents of the

University of California, at this time, must have had a memorable meeting. The acrimonious discussion that arose was apparently an unhappy affair for most if not all concerned. The committee on the internal administration was abolished by vote of the Board, Professor Colton's resignation was accepted, and Professor Holden was granted a leave of absence for three months, his salary to go on. From a statement made by one member of the Board of Regents it is probable that Professor Holden will soon tender his resignation as Director of Lick Observatory. Rumors are afloat that he may be made President of a scientific institution in the East in the near future. This surprising information comes to hand just as we go to press, and we have not space to say more now.

Loss of Library by Fire.—On September 14, 1897, at 1:30 A. M. the Grand Canyon Hotel in Flagstaff was discovered to be on fire; and within 20 minutes from the first alarm the entire building was in flames. Owing to the headway already made before the alarm was given, and the insufficiency of the water supply, and the consequent weakness of the fire department, all hope of saving the contents of the building was at once given up In this Hotel had been the office of Mr. Cogshall and myself ever since the beginning of our work with the Lowell Observatory, August 1, 1896; and our apartments contained all the mathematical, astronomical, physical and other books which I had brought with me from Chicago, or since purchased; besides various precious papers, letters, manuscripts, pictures, &c, and the records of our work on the double stars of the southern hemisphere. The night being unfavorable for observations we had retired; and in the hurried moments of darkness and confusion attending the evacuation of the burning building, we were barely able to save the records of the Observatory, the general manuscript catalogue of all double stars within 75° of the south pole, and a few other works such as the *Mecanique Celeste*—everything else, the library of books, the manuscripts, letters, pictures, personal effects, being a total loss.

As this destruction of the library will necessitate the formation of a new one, I beg to state that I am desirous of restoring first the astronomical works relating to the double stars of the southern hemisphere. If friends or other men of science with whom I have exchanged publications should have copies or reprints of their works which they would feel disposed to offer, I need hardly add that they would prove very useful and be received with grateful appreciation.

The writer hopes before long to offer to his correspondents another contribution: namely, the discoveries and measures of double and multiple stars in the southern hemisphere made at the Lowell Observatory, which fortunately he was able to rescue from the flames.

T. J. J SEE.

LOWELL OBSERVATORY, Flagstaff, Arizona, Sept. 16, 1897.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and to write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

Messrs. Wm. Wesley & Son, 28 Essex Street, Strand, London, England, are our sole European agents.

All correspondence and all remittances should be sent to

WM. W. PAYNE,
Northfield, Minn., U. S. A.